AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

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749.

Vol. XXXIII.—May, 1895.

THE TOPOGRAPHIC MAP OF THE UNITED STATES.

By HERBERT M. WILSON, M. Am. Soc. C. E.

READ MARCH 20TH, 1895.

It is the purpose of this paper to show something of the progress made and methods employed by the United States Geological Survey on the great topographic survey and atlas of the United States. Space will not be occupied with an argument for the uses, value and cost of topographic maps, nor with a detailed review of the work of other organizations in the making of such maps. These and many kindred subjects are well understood, and were ably treated by Mr. H. G. Ogden, of the United States Coast and Geodetic Survey, in a paper published in the *Transactions* of this Society*. A perusal of that paper will at once show how closely the methods which are employed by the Geological Survey agree with the standard set by the conference of Coast Survey topographers, and how far within the limit of cost set by that conference is the work done by the Geological Survey.

Until within recent years the United States was the most backward of all civilized nations in the making of topographic maps of its territory. Between 1867 and 1882 several independent government surveys were in existence, which mapped large areas of the undeveloped

* Vol. XXX, p. 62.

region west of the Mississippi River. Of these, the Wheeler survey mapped 360 000 sq. miles west of the 100th meridian. The results of this work were published in hachure topographic maps, of which about one-third were on the scale of 4 miles to 1 in., the remaining two-thirds being on the scale of 8 miles to 1 in. The King survey mapped 86 500 sq. miles adjacent to the Central Pacific Railroad, and this was published in 250-ft. contours, on the scale of 4 miles to 1 in. The Powell and Hayden surveys mapped 167 000 sq. miles in Utah and Colorado respectively, which area has been published in 250-ft. contours, on the scale of 4 miles to 1 in.

More recent and of far better quality is the work of the United States Coast and Geodetic Survey and the United States Lake and River Surveys of the Engineer Corps of the United States Army, which organizations have mapped and published, on large scales and in contours, a narrow strip of topography along the entire coast and lake shores, and the Mississippi, Missouri and a few other rivers.

Besides the above a number of states, notably New Hampshire, New Jersey, Pennsylvania, Wisconsin, Kentucky and Minnesota, have made topographic maps of all or portions of their areas, on scales ranging from 1 : 1 600 to 1 : 250 000, some of which are published in contours. The State of Massachusetts has nearly completed a town boundary survey, based on a system of primary triangulation which furnishes numerous control points on every town line. This affords an excellent basis on which to conduct future topographic surveys of any degree of detail.

In addition to the material which is available in map form for the making of topographic maps on various scales, there is in existence a large amount of matter suitable as primary mathematical control, which is the result of triangulation conducted by the Missouri and Mississippi River Commissions, the Gardiner State Survey of New York, the United States Lake Survey, and particularly the United States Coast and Geodetic Survey. These sources render available about 10 000 points, the positions of which have been determined, and though some of the territory covered by them has already been mapped by the Geological Survey, they furnish the foundation upon which to base topographic surveys of a large area of the country. The work of these organizations must be supplemented in many places by additional triangulation, in order to furnish at least two

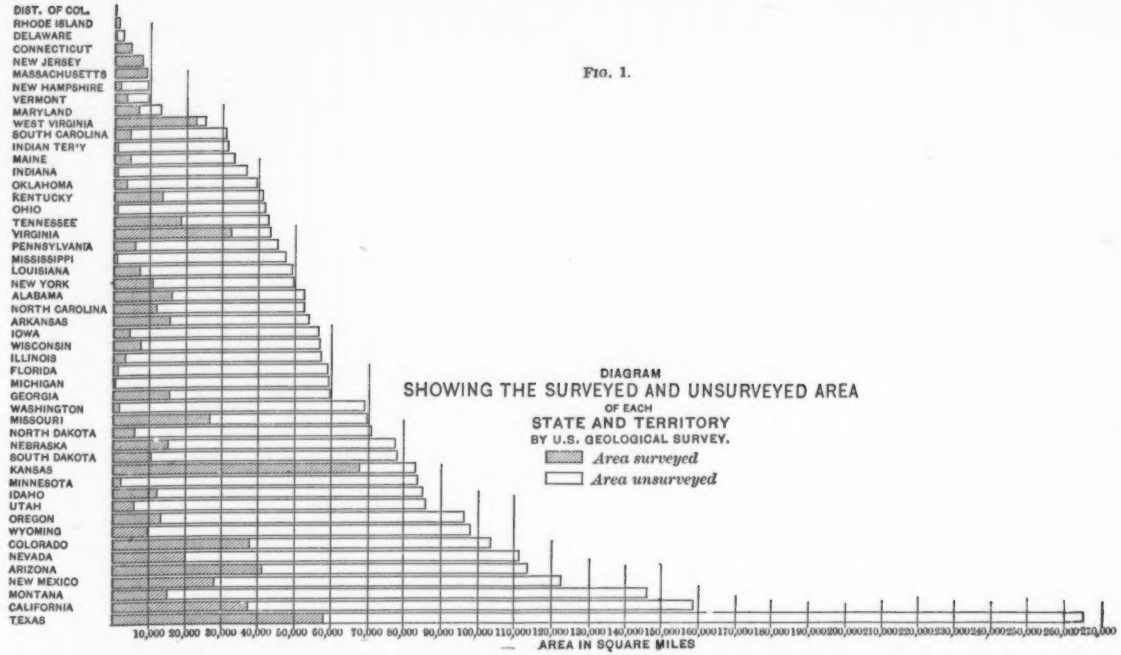
points for the control of each atlas sheet of the Geological Survey. The positions have been tabulated, and are accessible to the public in Nos. 122 and 123 of the *Bulletins* of the Geological Survey.

Besides this primary horizontal control, there is a vast amount of material available as level bench marks and secondary control, such as railway, canal, city and special private surveys, and the subdivision surveys of the public land system. This material is collected, tabulated and adjusted by the Geological Survey, so that its precise value is well known, and it is thus made available for immediate use. The elevations have been adjusted and reduced to mean sea level and the results published in a "Dictionary of Altitudes," forming *Bulletin* No. 76 of the Geological Survey.

Since 1882 the United States Geological Survey has been actively engaged in making a topographic survey of the country. This work, although primarily inaugurated as a necessary adjunct to a geological survey, has made rapid gains in popular favor, the maps being adapted not only to the needs of the geologist, but to all engineering and economical requirements which their scales will satisfy. The scales at first adopted were 1: 62 500, 1: 125 000 and 1: 250 000, or approximately 1 in. to 1, 2 and 4 miles. The latter scale was abandoned several years ago as being too small. These maps show the surface conformation of the country in contour lines, the intervals between which range from 5 to 250 ft., though contour intervals greater than 100 ft. have been abandoned in recent years.

This topographic survey is being prosecuted simultaneously in all portions of the country, some work having been done in every state and territory. The results are published in atlas sheets of nearly uniform size, bounded by parallels of latitude and meridians of longitude in such manner that the whole may form a continuous and connected atlas of the entire country, regardless of political or natural boundary lines. The atlas sheets upon the 1 mile to 1 in. scale cover 15 minutes each of latitude and longitude, and those upon the 2 miles to 1 in. scale 30 minutes in each direction. Many thousand such sheets will be required to cover the country. Thus far 906 sheets have been surveyed and 775 engraved and published. Of those surveyed 483 are upon a scale of 1: 62 500; 361 upon a scale of 1: 125 000, and 62 upon a scale of 1: 250 000. The accompanying diagram (Fig. 1) shows the area of each State which has already been surveyed.

FIG. 1.


DIST. OF COL.
RHODE ISLAND
DELAWARE
CONNECTICUT
NEW JERSEY
MASSACHUSETTS
NEW HAMPSHIRE
VERMONT
MARYLAND
WEST VIRGINIA
SOUTH CAROLINA
INDIAN TER'Y
MAINE
INDIANA
OKLAHOMA
KENTUCKY
OHIO
TENNESSEE
VIRGINIA
PENNSYLVANIA
MISSISSIPPI
LOUISIANA
NEW YORK
ALABAMA
NORTH CAROLINA
ARKANSAS
IOWA
WISCONSIN
ILLINOIS
FLORIDA
MICHIGAN
GEORGIA
WASHINGTON
MISSOURI
NORTH DAKOTA
NEBRASKA
SOUTH DAKOTA
KANSAS
MINNESOTA
IDAHO
UTAH
OREGON
WYOMING
COLORADO
NEVADA
ARIZONA
NEW MEXICO
MONTANA
CALIFORNIA
TEXAS
DIAGRAM
SHOWING THE SURVEYED AND UNSURVEYED AREA
OF EACH
STATE AND TERRITORY
BY U.S. GEOLOGICAL SURVEY.
Area surveyed
Area unsurveyed
10,000 20,000 30,000 40,000 50,000 60,000 70,000 80,000 90,000 100,000 110,000 120,000 130,000 140,000 150,000 160,000 170,000 180,000 190,000 200,000 210,000 220,000 230,000 240,000 250,000 260,000 270,000
AREA IN SQUARE MILES

These topographic maps are engraved upon copper, three plates being required for each sheet. Culture, or the work of man, is printed in black; drainage or hydrography in blue; and contours or relief features in brown. All cultural features which are of a public nature, as roads, paths and trails, railways, dams, piers and breakwaters, are shown. Private culture, with the exception of houses, is not represented. This limitation has been made in order to reduce the number of conventional signs to the fewest possible, and because private culture is of little general interest. All streams, fresh and salt marshes, canals and lakes, are shown, the conventions for these being simple and readily intelligible. The surface conformation is shown chiefly in contours, though brown dots are occasionally used on sand or flood plains. Hachures are sometimes employed on exceedingly steep bluffs, and depressed contours, as pot-holes, are indicated by hachuring on the inner side of the contour line and by frequent numbering. The outlines of all timbered areas are mapped in the field and are recorded on the manuscript maps in a uniform green tint, though as yet they are not published on the engraved maps.

The field upon which the Geological Survey is at work is diversified; it comprises broad plains, high and rugged mountains, plateaus and low, rolling hills. Some portions of the country are densely populated, others are almost devoid of settlement, and others are covered with a dense growth of forests. It is by reason of this diversity of conditions that maps of different areas differ in scale, and the difference in natural conditions and scale must result in the employment of different methods of work. In general, it may be said that the more populous portions of the East and of the Pacific Coast are mapped on the larger scales, while less inhabited portions of the country are mapped on the smaller scale; also that the methods of survey which work to advantage in the high mountain regions of the West or in the Appalachian Hills of the East are more or less inapplicable to the flat plains region of the Mississippi Valley and to the forested plains in the northern portion of the country.

From a constructive point of view, a map is a sketch corrected by locations. The making of locations is geometric, that of sketching is artistic. However numerous may be the locations, they form no part of the map itself, but serve only to correct the sketch, the latter supplying the material of the map. The correctness of the map depends

upon, 1, the accuracy of the locations; 2, their number per square inch of map; 3, their distribution, and 4, the quality of the sketching. The first three of these elements define the accuracy of the map, and the greatest accuracy is not always desirable because it is not economical. The highest economy is in the proper subordination of means to ends; therefore the quality of the work should be only such as to insure against errors of sufficient magnitude to appear upon the scale of publication. The above being recognized, it is evidently poor economy to execute triangulation of geodetic refinement for the control of maps upon small scales, and providing the errors of triangulation are not such as are cumulative, the maximum allowable error of location of a point on which no further work depends may be set at $\frac{1}{100}$ in. on the scale of publication. The second condition, the number of locations for the proper control of the sketching, is not easily defined. It depends largely upon the character of the country, and explanation will be made later of the amount of control which the topographers of the Geological Survey have accepted as sufficient for the various scales and regions of their work. The same is true of the third element of accuracy, that of the distribution of locations; while the fourth element, the quality of the sketching, depends wholly upon the artistic skill of the topographer; or, in other words, upon his possession of the topographic sense, which may be described as his ability to see things in their proper relations and his facility in transmitting his impressions to paper. This is by far the most important and difficult requirement to meet, and one which takes a longer apprenticeship on the part of the topographer than all the others combined.

The work involved in making a topographic map comprises four operations: First, the location of the map upon the earth's surface by means of astronomic observation; second, the horizontal location of points, which is usually of three grades of accuracy, primary triangulation or primary control traverse, secondary triangulation, and ordinary traverse for the location of details; third, the measurement of heights, which usually accompanies the horizontal location and may similarly be divided into three classes in accordance with their degree of accuracy; and fourth, the sketching of the map.

Where primary triangulation executed by the United States Coast and Geodetic Survey and equally careful organizations is not already in existence, it becomes necessary to measure and expand a base line

and to execute a system of primary triangulation in sufficient detail to establish at least two points on each atlas sheet. Base lines are measured by the Geological Survey with a steel tape, the length of which is 300 ft., and which is carefully compared at an observed temperature with the standard of the United States Coast and Geodetic Survey, both before entering and after leaving the field. The probable error of several base lines which have been carefully measured with steel tapes by the Geological Survey is so small as to be inappreciable upon the future control work, and is nearly as small as the best results obtained by the old-time expensive system of measuring with base bars. At first compensating bars were used, but experience showed that longer bases, simplifying the expansion and placed at more frequent intervals, were more economic and gave equally good results.

The base having been measured, the astronomic position of one of its ends is determined with the greatest precision. It is not necessary to check the subsequent triangulation by frequent astronomic observations, as they are less accurate than triangulation. Astronomic checks on primary triangulation are therefore introduced only about every 200 to 300 miles. The latitude of the desired position is determined by means of a combination instrument, which is at the same time an astronomic transit and zenith telescope, by Talcott's method, by measuring the differences of zenith distance at the culmination of two stars which culminate on opposite sides of the zenith. The longitude is determined by telegraphic comparison of local time at two stations, the longitude of one of which is known. This involves the determination of the errors of the chronometers used, which is accomplished by the observation of transits of stars across the hairs of transit instruments which are set in the meridians of the places of observation, and recording the same on a chronograph. The initial direction or azimuth of the base line is determined with the theodolite used in triangulation, by measuring the horizontal angle between some close circumpolar star, usually Polaris, and a terrestrial mark. Correction azimuths are also determined about every 100 miles in a system of primary triangulation, and about every 10 to 20 miles in primary traverse.

The work of primary triangulation and its expansion from the base, consists in the selection of stations, in the erection of signals, and in the measurement of angles. Stations are so selected as to give the best shaped triangles and so as to group these into simple quadrilateral,

pentagonal or similar figures. They are also so located as to serve best the needs of the topographer. This requires that they shall offer suitable bases from which to expand the secondary triangulation, and that at least two, preferably three, points, shall fall within each atlas sheet. The signals used differ according to the nature of the country; on the plains a simple signal pole may be erected, or an observing scaffold may be required on which to elevate the theodolite. On bare hills a cairn of rocks may be built; and on wooded hills all the timber may be removed, leaving a signal tree, or sight lines only may be cleared and heliotropes used as signals. Angles are measured by means of theodolites having 8-in. circles, reading by micrometer microscopes to two seconds (see Fig. 2). Great care is taken in the adjustment and placing of the instrument, and in shading it from the sun and sheltering it from the wind. Several series of angles are always observed on each station, both singly and in combinations. Moreover, the telescope is transited at suitable intervals to eliminate eccentricity, and readings are taken on various points of the circle to eliminate errors of graduation.

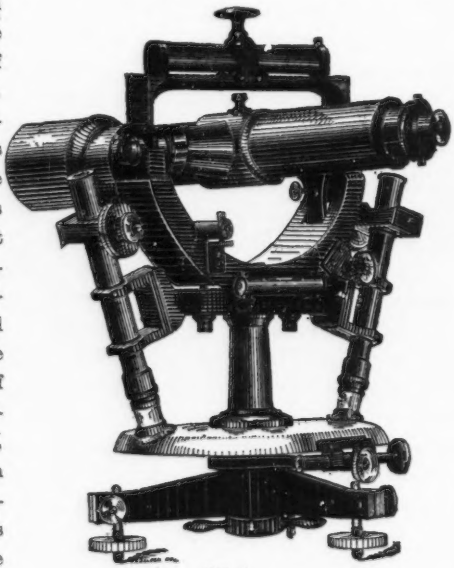


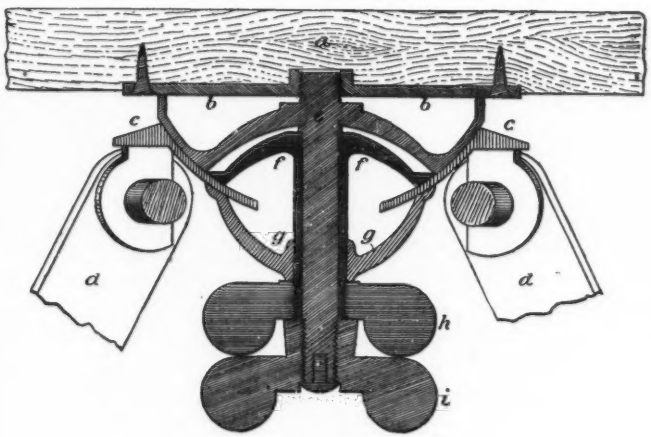
FIG. 2.

In a level country, especially if covered with forests, it is very expensive and sometimes practically impossible to carry on primary triangulation. In such cases the map control is obtained by a system of primary and secondary traverse lines. For primary control, the positions of the initial and terminal points of the traverse are determined by astronomic methods, and in addition to the initial azimuth,

others are observed every 10 or 20 miles in the progress of the work. The directions are measured by an instrument reading to 10 seconds, and the distances by a 300-ft. steel tape. These traverses are run with great care, preferably over a line of railroad in order to get the best grades and alignment; each deflection angle is read at least three times; and the tape is corrected for slope and temperature and reduced to sea-level as in a base measurement. The lines are finally plotted after computing the latitudes and departures, and correcting the courses for convergence of meridians.

The primary triangulation being completed, a preliminary computation of the positions and distances between stations is made in the field

JOHNSON PLANE-TABLE HEAD



a. Plane Table board
b Bearing Plate
c. Tripod Head
d_1 " Legs
e. Azimuth Cup
f. Upper Level Cup
g. Lower " "
h. Level Clamp
i Azimuth Clamp

FIG. 3.

and these data are furnished the topographer as a basis on which to construct his graphic or plane-table triangulation. From this point forward all of the work is represented on the plane-table sheets, thus requiring the keeping of no cumbersome notes which must be worked

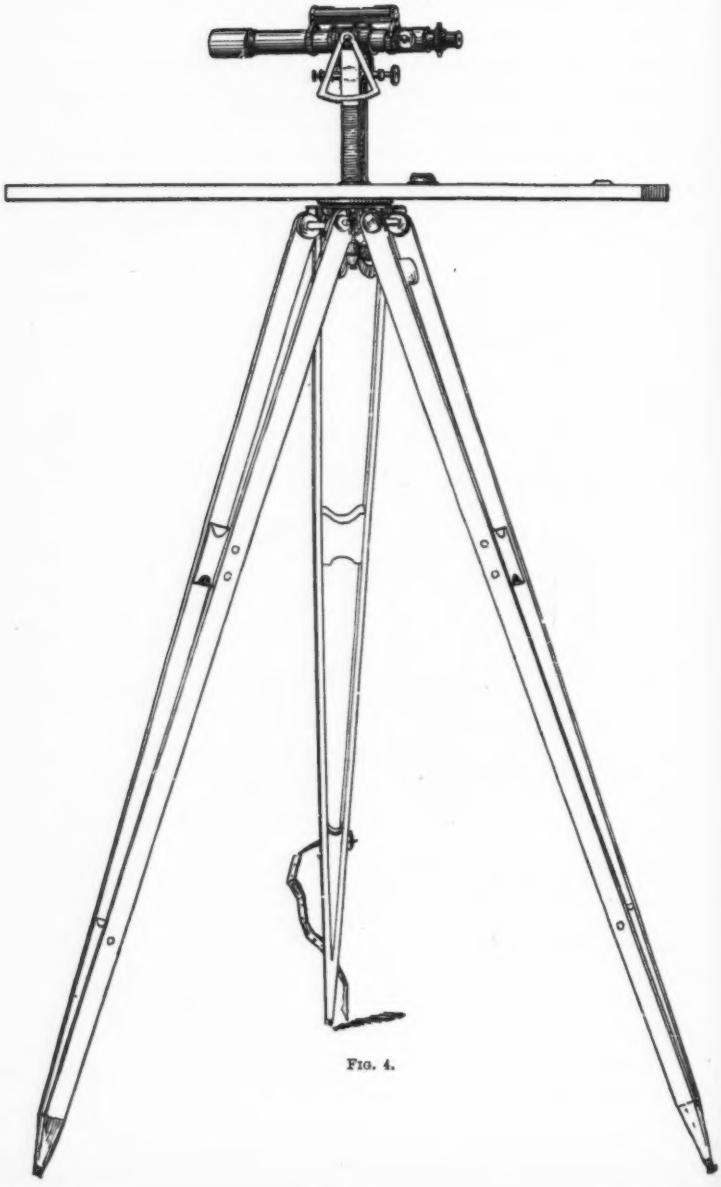


Fig. 4.

up at some future time in the office, while the progress of work from day to day is always observable.

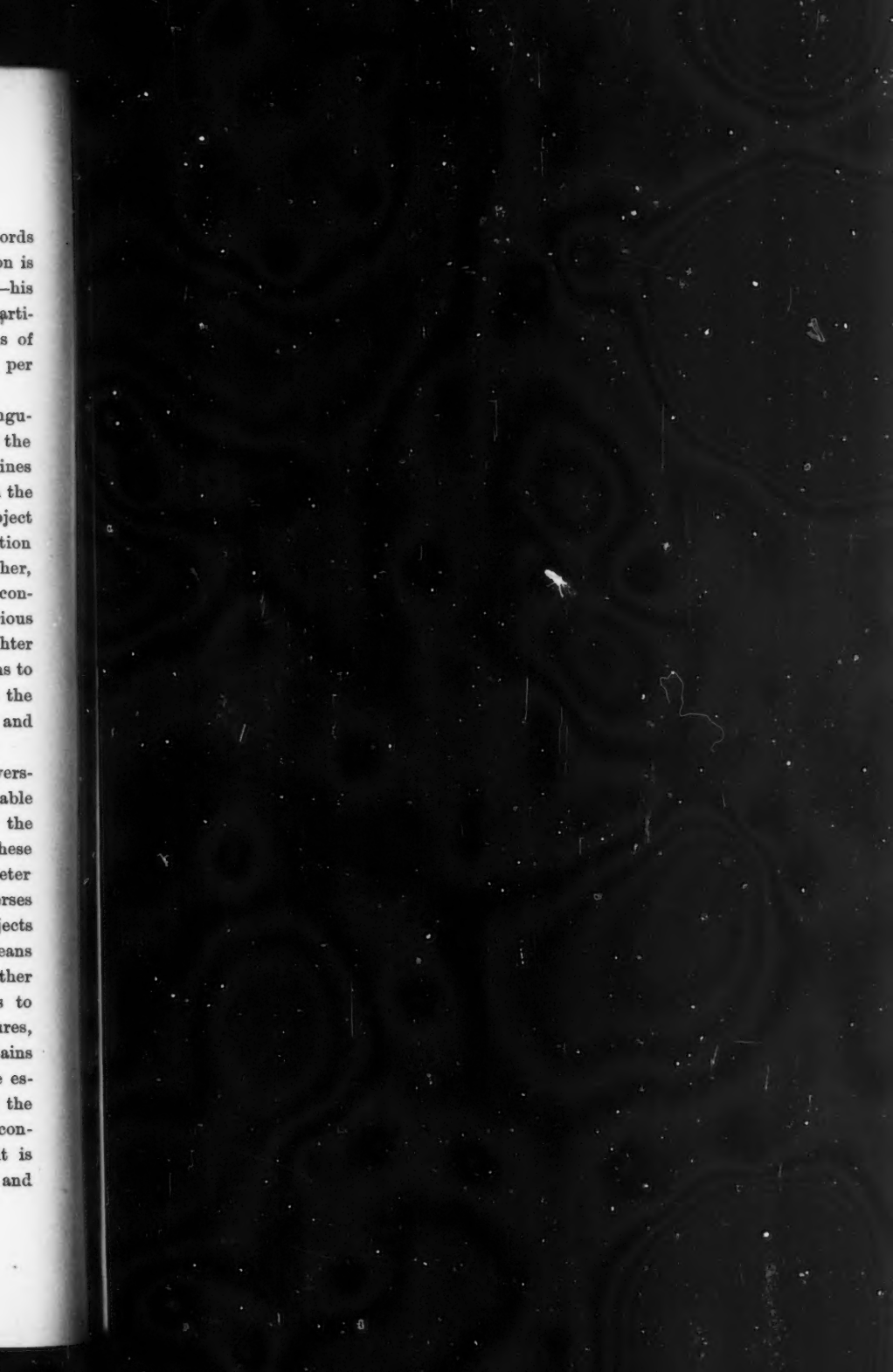
The Johnson plane-table in use in the Geological Survey was designed by one of the topographers of the bureau and is neither so heavy nor so cumbersome as the old-style plane-table, yet it combines the elements of stability, lightness and firmness in a remarkable degree. The peculiarity of this instrument consists in the tripod head (Fig. 3). This is compact and firm, is leveled by a ball-and-socket joint instead of leveling screws and has no tangent motion, being moved by the long lever arm of the board. The alidade used is of the best make and is provided with stadia hairs, a vertical circle reading to minutes, and a ruler 18 to 24 ins. in length (see Fig. 4). Use is not made of large plane-table sheets which have to be rolled up and from which the work has to be carried from one sheet to the other, thus requiring their shifting in the field. Each plane-table sheet is complete within itself, and on it little is recorded other than the graphic triangulation and a little sketching of the immediate summit of the hill occupied. Each of these sheets is of the size of a completed atlas sheet and is made of double-mounted paragon paper, two sheets of paper being backed, one on either side of a piece of stretched muslin, the grain of the paper being crossed to prevent warping.

On taking the field the topographer has, in addition to the triangulation points accurately plotted upon his plane-table sheet, all such data as he has been able to gather from railway surveys, city engineers' offices, county surveyors, or from state or national organizations, so that he is able to make the best use of such material as has been obtained from prior surveys, examining and checking this in the field in order to assure himself whether it is sufficiently correct for adoption. He first makes a hasty reconnoissance of the region to be mapped, which, for an atlas sheet on the 1-mile scale, is about 220 sq. miles in area, and he finds little difficulty in driving over this in from 6 to 10 days, choosing from 15 to 20 suitable plane-table stations and erecting signals thereon. These signals are of the most temporary character, consisting usually of a properly braced rail or pole from 10 to 15 ft. in height, on which a cloth flag about 1 yd. square is fastened. He then proceeds to occupy each of his stations in succession, obtaining intersections upon other chosen stations and upon all such objects as hilltops, lone trees, church steeples, houses, etc., as will probably be seen

and speedily identified from other stations. He also reads and records vertical angles to all these objects, so that when his triangulation is completed—and this process rarely takes longer than a month—his plane-table sheet has located upon it a great many natural and artificial objects, the vertical elevations and the horizontal positions of which are recorded. The number of these positions averages $1\frac{1}{2}$ per square mile or per square inch of map area.

Plate XXXIV is a characteristic illustration of the graphic triangulation executed in the field, on the plane-table board, in making the topographic maps of the Geological Survey. The various sight-lines from one occupied station to another, which are drawn in pencil on the field sheet for obtaining intersections which shall locate the object sighted, are here reproduced in red. The three primary triangulation stations, and those accordingly first occupied by the topographer, Giant Mountain, Hurricane Mountain, and Blueberry Hill, are connected by the heaviest lines. The sight-lines from these to the various occupied stations, and between the latter, are shown in a lighter line. The finest lines are drawn from the various occupied stations to the numerous tertiary locations, which were not occupied by the topographer. Vertical angles were taken to all of these points and their elevations computed within a few feet.

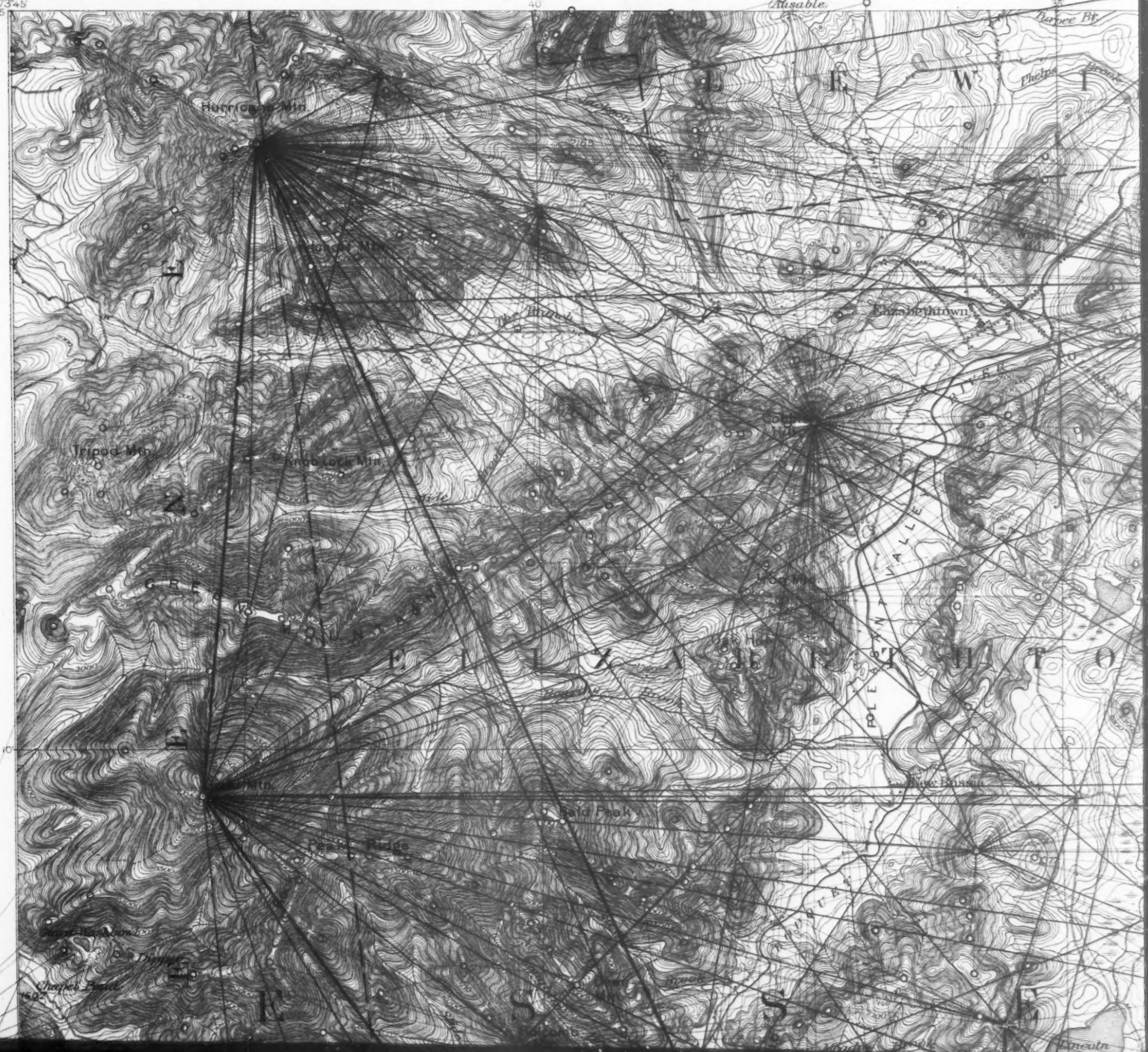
Meanwhile the assistants to the topographer are carefully traversing all roads, for which purpose they use a lighter form of plane-table having no leveling apparatus, on which is a compass needle, the alidade employed being an open-sight ruler 10 ins. long. With these instruments and with the aid of distances measured by an odometer on the wheel of the buggy in which he rides, the assistant traverses every road in the area to be surveyed. He sights to natural objects in the road, usually a sharp bend, orienting his board by means of the compass needle. He sets up his instrument at every other station, taking fore and back sights, and plots frequent lines to the prominent objects about him, as hilltops or other salient features, which he thinks the topographer may locate. In this way he obtains a means of connecting his work with that of the topographer, more especially as he locates all houses on the line of his traverse, and the topographer intersects on many of these. An expert traverseman conducts his work with such skill that, for the scale on which it is plotted—1 mile to 1 in.—scarcely any perceptible error occurs, and



U.S. GEOLOGICAL SURVEY.
J.W. POWELL.
DIRECTOR.

PLATE XXXIV.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXIII, No. 749.
WILSON ON U. S. TOPOGRAPHIC MAP.

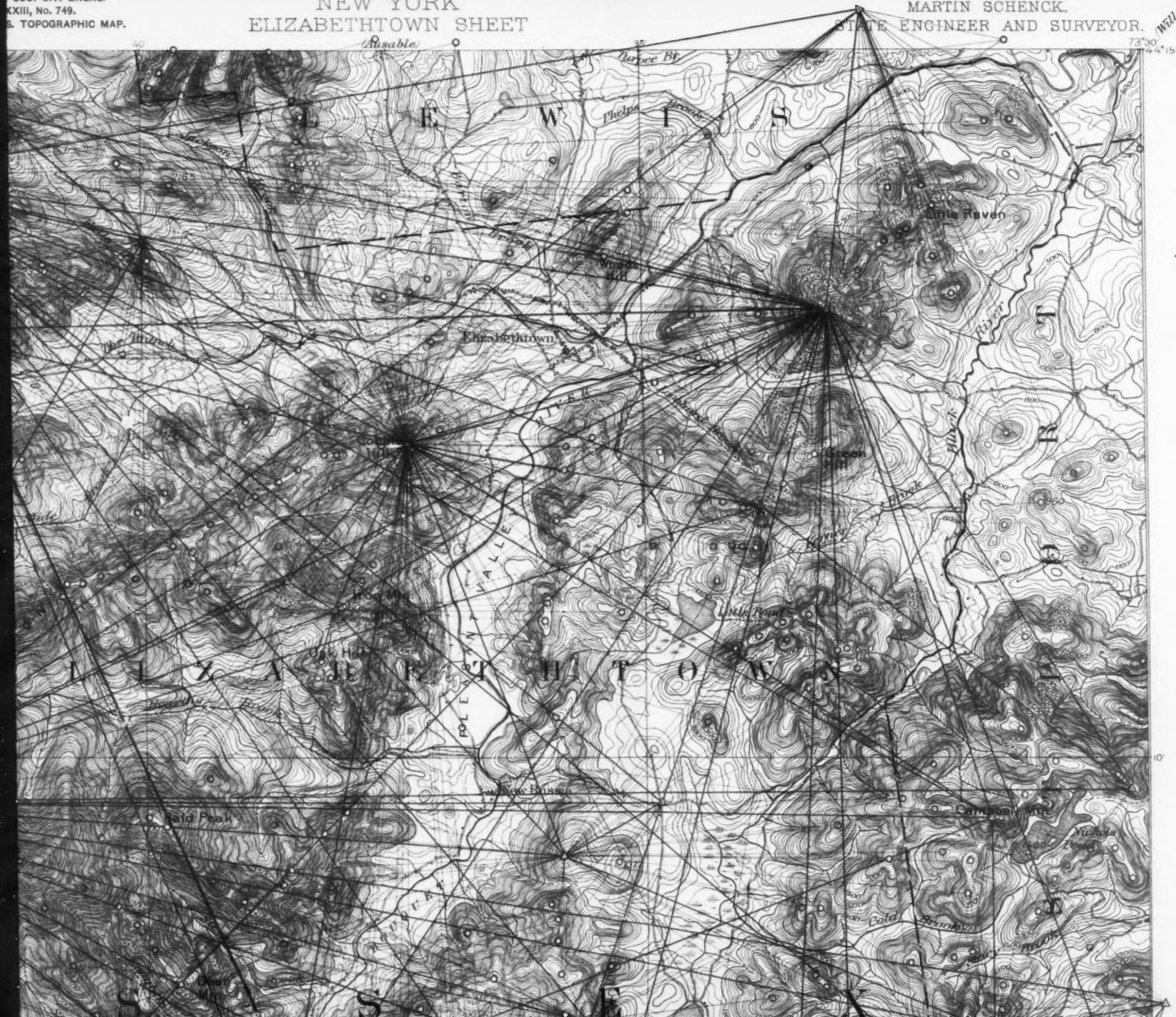
DIAGRAM OF TRIANGULATION
NEW YORK
ELIZABETHTOWN SHEET

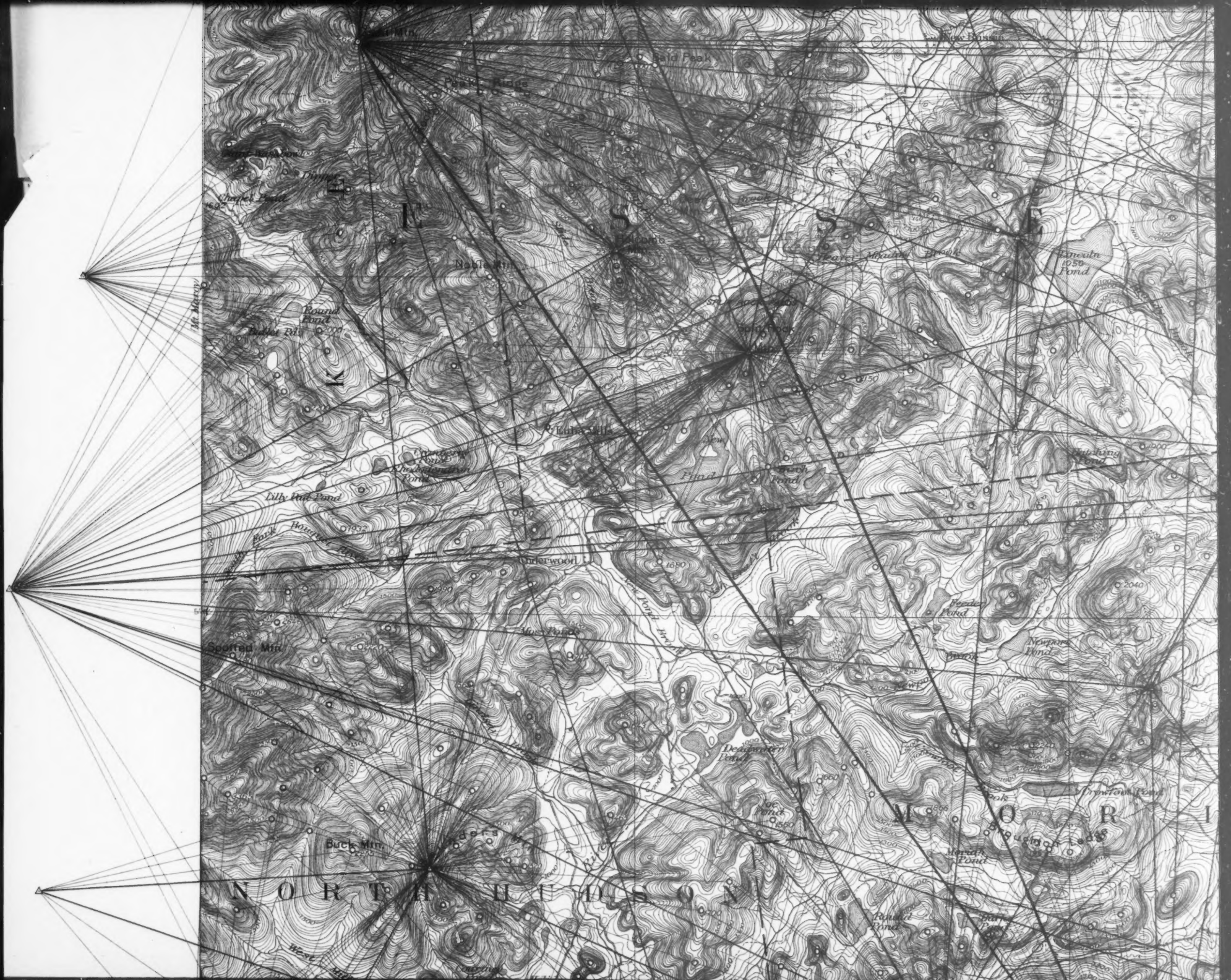


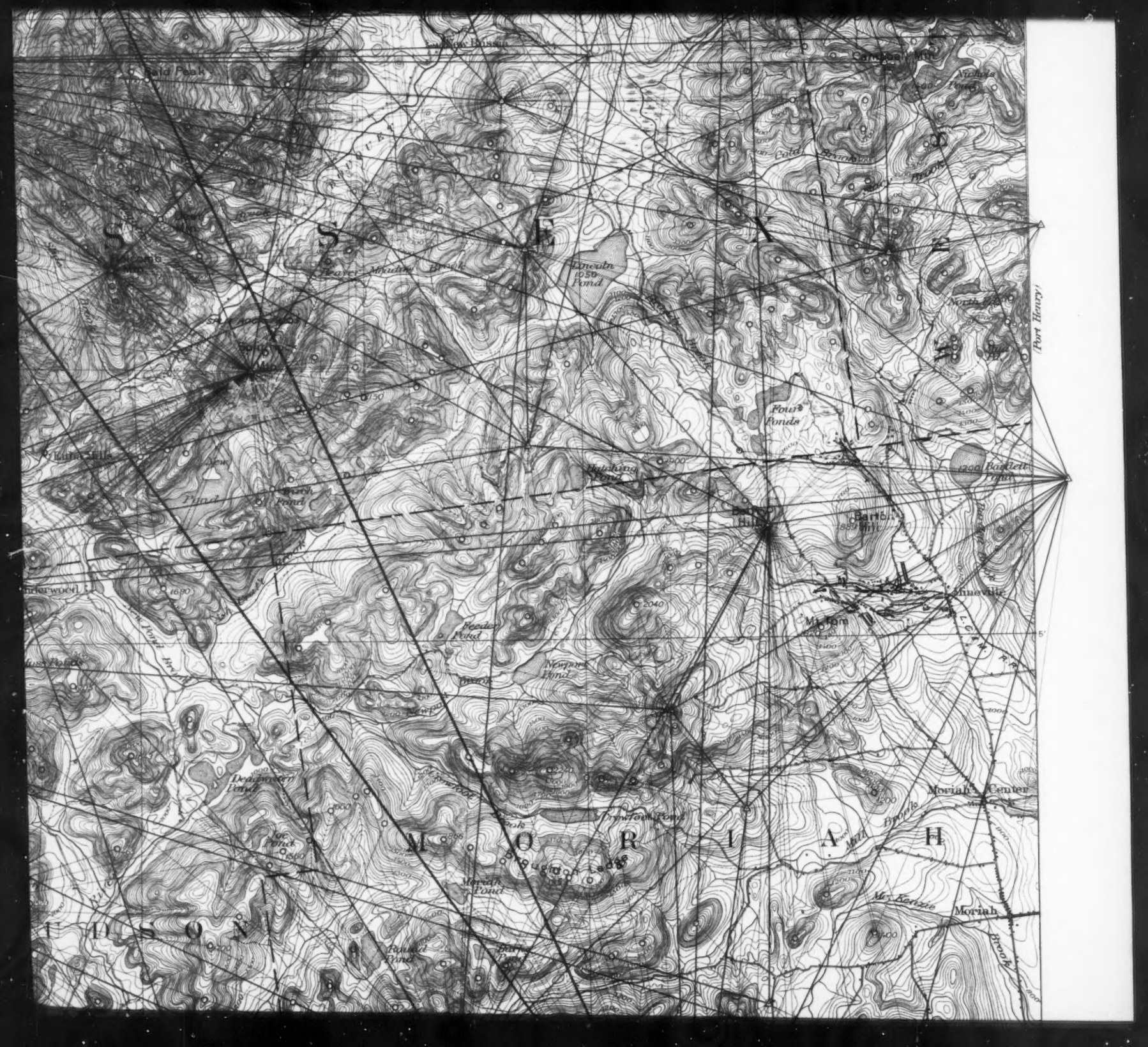
TE XXXIV.
SOC. CIV. ENGRS.
XXIII, No. 749.
S. TOPOGRAPHIC MAP.

DIAGRAM OF TRIANGULATION
NEW YORK
ELIZABETHTOWN SHEET

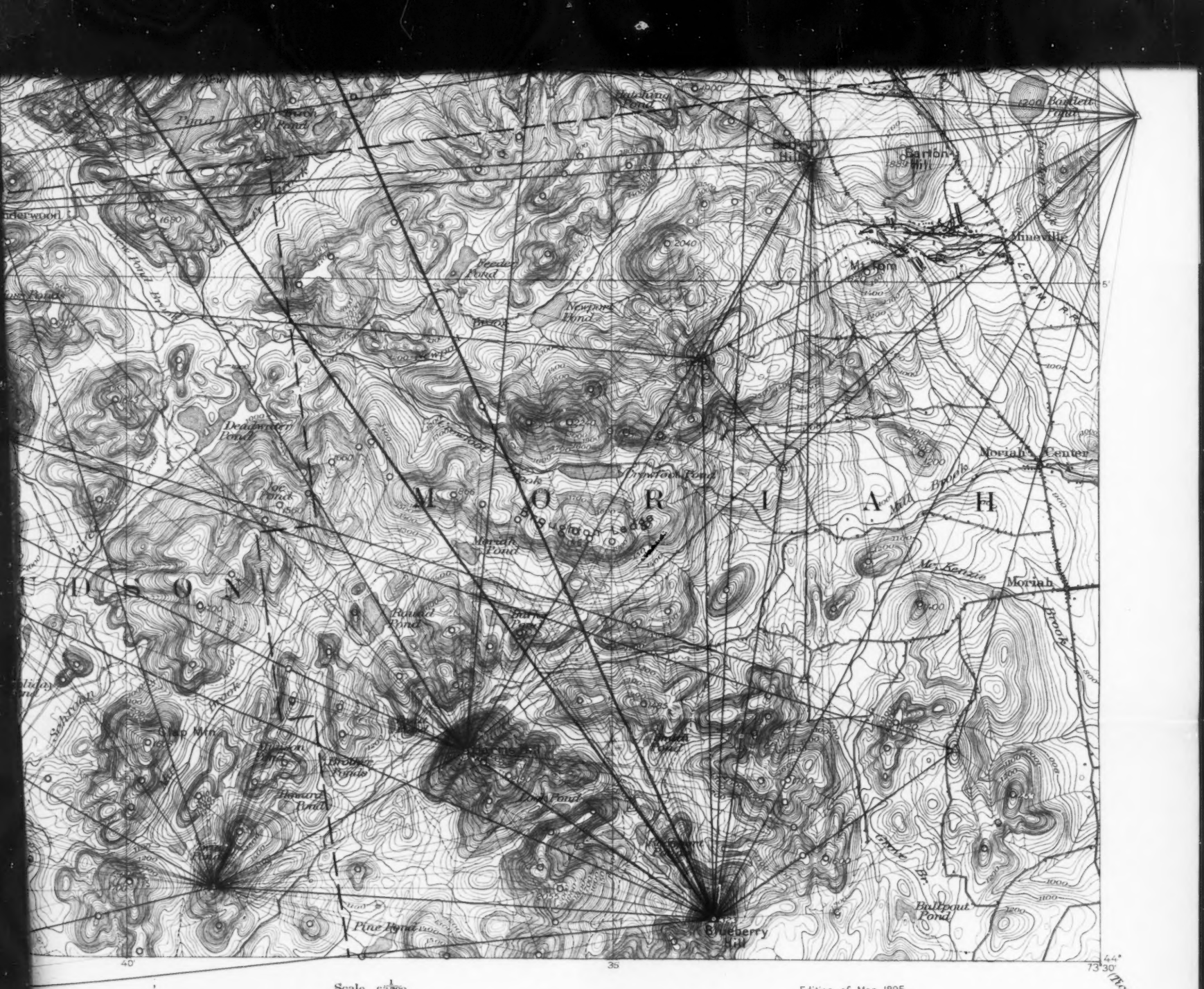
STATE OF NEW YORK.
MARTIN SCHENCK,
STATE ENGINEER AND SURVEYOR.




Bald Peak
Peaked Ridge
Noble Mtn.
Mt. Macey
Round Pond
Lilly Pad Pond
Lake Mills
Underwood
Spotted Mtn.
Buck Mtn.
Deadwater Pond
Ice Pond
Beaver Meadow Brook
Jimeson Pond
Feeder Pond
Newman Pond
Mud Pond
Round Pond
Pond
NORTH HUDSON
WEST


Bald Peak
Nichols Pond
Cold Brook
Beaver Mountain Brook
Linneatn 1050 Pond
Four Ponds
Port Henry
Bartlett Pond
Barton Hill
Barton Mine
Mt. Tom
Moriah Center
Mt. Kervie
Moriah
Brook
Deadman Pond
Moriah Pond
Newport Pond
Feeder Pond
Brook Pond
Underwood
Luna Mills
Mud Brooks
L.C.R.R.
MORIAH
ESSEX

Lilly Pad Pond
Underwood
Spotted Mtn.
Buck Mtn.
NORTH HUDSON
Dog Mtn.
Little Tar Mtn.
Old Far Mtn.
Cap Mtn.
Blueberry Hill
Pine Pond
Deadwater Pond
Holiday Pond
Newport Pond
Meader Pond
Farnsworth Pond
Bluff Pond
Beech Pond
Hatchery Pond
Ice Pond
Maple Pond
Moss Pond
Bullhead Pond
Bog Pond
Bear Pond
Bark Pond
Bear Brook
West Mill Brook
Schroon
Boquet
Ausable
Hudson
Lake Sanford
Lake Harris
Lake Algonquin
Lake Colden
Lake Tear of the Clouds
Lake Henderson
Lake Adirondack
Lake Arnold
Lake Jimmy Jones
Lake Marcy
Lake Avalanche
Lake Sandy
Lake Cliff
Lake Colvin
Lake Tahawus


Scale 6 1/2 inches
1 0 1 2 3 4 Miles
Contour Interval 20 feet
Datum is mean Sea level
Edition of Mar. 1895.
LEGEND
Primary sight lines
Secondary sight lines
Intersection sight lines
Primary triangulation stations
Secondary triangulation stations
Triangulation locations
Moriah
Moriah Center
Mineville
Barton Hill
Blueberry Hill
Pine Pond
Bullpout Pond
Dead Creek Pond
Newport Pond
Marsh Pond
Hammond Pond
Lost Pond
Mill Brook
Moriah Brook
Cook Br.
Sep Mtn
Schroon
Mt. Kerrize
Mt. Hom
Bartlett Pond
Hutching Pond
Beech Pond
Deadwater Pond
Bloomfield Pond
Brodock Ponds
Howard Pond
Bloughton Ledge
Trumbull Pond
Bullpout Pond
L. O. & W. R.R.
40'
35
44° 73° 30'
(Ironderoga)

fairly large circuits which tie to the located points of the topographer, close with rarely an error exceeding $\frac{1}{40}$ in. The average traverseman will cover about 12 miles a day. In addition to these road traverses, paced foot traverses are occasionally run between the roads where they are far apart, or where plane-table intersections cannot be obtained, so that on an atlas sheet the amount of located traverse work will average 2.2 miles per square mile or inches per square inch of paper.

Where there are not enough roads to afford sufficient traverse or instrumental control on which to base the sketching, the stadia is used in measuring distances on additional cross-country traverses. In such cases sketching and the determination of elevations by vertical angles are carried on simultaneously with the traversing, as it would be impossible to retrace the lines so run. In extreme cases, as in the Adirondack forests, northern Minnesota and western Washington, where the dense undergrowth precludes the use of the stadia, distances are measured by the engineer's chain. The stadia is also employed in traversing the outlines of bodies of water and in the topographic survey of such regions as southern Louisiana, where the flatness of the slopes requires the use of a 5-ft. contour interval, the elevations in this case being determined by spirit level.

In order to obtain sufficient bench marks on which to base the subsequent and less accurate elevations, an assistant topographer runs a number of spirit-level lines across each sheet, connecting them with some railway or other bench which has been adjusted through from mean sea-level. These spirit-level lines are not usually further apart than 5 miles, the equivalent of two or three being run the length of, and one or two across, each sheet. Thus is furnished also an excellent check to the vertical angle work of the topographer. The average number of spirit and trigonometric level elevations is about $2\frac{1}{2}$ to each square mile or square inch of paper.

As this work progresses the traverses are adjusted to the triangulation locations of the topographer, any little errors which may have occurred in the former being eliminated in the course of this adjustment, and the topographer is now ready to sketch contours, having as a base upon which to do this sketching a sufficient amount of mathematical control.

Plate XXXV is similar to Plate XXXIV in that it shows all the

points located by the graphic plane-table triangulation, but differs from it in being divested of the sight-lines showing how these locations were obtained. In addition, there are brought out in red on this sheet all of the roads or trails over which instrumental traverse lines were run, and by little solid dots locations obtained by intersection from this traverse are shown. The result is a complete exposition in red lines, circles and triangles of the amount of instrumental control on which the sketching is dependent. The elevation of every triangulation location, of whatever degree, is known, as well as its horizontal position, and this aids the topographer in sketching the contours of the higher relief. Elevations obtained along all of the traverse lines, in addition to their horizontal location, afford the topographer mathematical control and data on which to base his sketching of the valley bottoms and the lower relief.

Taking this sketch sheet in his lap, the topographer now drives over every road, and where these are not sufficiently near together, walks in between them and sketches the contours as far as he can safely see them on each side of his path. In performing this operation he starts out from some fixed point, as a road junction or a located house, the elevation of which is known, and setting his aneroid at this elevation, he drives along, recording and marking the points at which the various 20-ft. contours cross his path. The aneroid being an unreliable instrument, he is careful not to drive more than 2 to 4 miles without checking it on a well-determined elevation. He is usually able to do this by connecting with houses or crossing hills, the elevations of which have been previously determined, as above described. If he is not able to so check his aneroid, he hastily sets up his plane table and reads a few vertical angles to hilltops or houses within sight, the elevations of which are known, and with the aid of these angles and the distances, which he can measure on his adjusted sketch sheet, he is able at once to compute the elevation of his position within 3 or 4 ft., and thus to check his aneroid. In this way the sketching of the topography should never be out in elevation more than 20 ft., or one contour interval. In the course of this work the elevations of about 13 points per square mile or per square inch of paper are determined, so it will be readily seen that the sketching of the topography is not likely to be far wrong in elevation. The topographer thus sketches the whole of the area assigned him, not only mapping

U.S. GEOLOGICAL SURVEY.
J.W. POWELL,
DIRECTOR.

DIAGRAM OF CONTROL
NEW YORK
ELIZABETHTOWN SHEET

PLATE XXXV.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXIII, No. 749.
WILSON ON U. S. TOPOGRAPHIC MAP.

DIAGRAM OF CONTROL
NEW YORK
ELIZABETHTOWN SHEET

PLATE XXXV.
TRANS. AM. SOC. CIV. ENGRS.
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WILSON ON U. S. TOPOGRAPHIC MAP.

STATE OF NEW YORK.
MARTIN SCHENCK,
STATE ENGINEER AND SURVEYOR.

Grant Mtn.
Bald Peak
Peak
Ridge
New Britain
Mt. Marcy
Round Pond
Euba Hills
Rhododendron Pond
Lilly Pad Pond
South Fork Bouquet River
Underwood
Moss Ponds
Spotted Mtn.
Buck Mtn.
Split Rock Mtn.
Split Rock
Pond
Beech Pond
Deadwater Pond
Crawford Pond
Moriah Pond
Braglon
Bouquet
Monday Brook
Vanetta
Pond
Feeder
Pond
Newman
Pond
Hatching
Pond
Fern
Pond
Birch
Pond
Ice
Pond
Round
Pond
Pond
NORTH HUDSON
S E
M O R I

Bald Peak
New Russia
Campbell Mtn.
Fishers Pond
Cold Brook
Lincoln Pond
Four Ponds
Bartlett Pond
Barton Hill
Belfry Hill
Mineville
Mt. Tom
Moriah Center
Moriah
Mt. Kenzie
Port Henry
Pond
Beaver Meadow Brook
Mill Brook
Bradley Brook
Bruegleon Pond
Moriah Pond
Randall Pond
SOUTH MORIAH

ENGRAVED BY U.S.G.S.

Henry Gannett, Chief Topographer.
H.M.Wilson, Geographer in charge.
Triangulation by U.S.Coast and Geodetic Survey.
Topography by E.C.Barnard.
Surveyed in 1892.

Scale $6\frac{1}{2}\frac{1}{500}$

1 ½ 0 1 2 3 4 Miles

Contour Interval 20 feet

Datum is mean Sea level

Ed

Elevations of a
Primary triang
Secondary tria
Triangulation
Traverse locati
Traverse lines

Belfry Hill
Barron Hill
Minerville
Mt. Tom
L. C. & M. R. R.
Moriah Center
Mill Brook
Mc. Kenzie
Moriah
Brook
Dead Water Pond
Ice Pond
Crawford Pond
Braughton Lead
Moriah Pond
Round Pond
Beede Pond
Trout Pond
Clap Mtn.
Munson Pond
Brother Ponds
Harris Hill
Howard Pond
Look Pond
Smith Pond
Twin Ponds
Rockmont Ponds
Bullpout Pond
Pine Pond
Blueberry Hill
Moondergogal
40
35
44°
73°30'
Scale 1/62500
Miles
Contour Interval 20 feet
Datum is mean Sea level
Edition of Mar. 1895.
LEGEND
Elevations of all control points and lines are determined.
Primary triangulation stations
Secondary triangulation stations
Triangulation locations
Traverse locations
Traverse lines

the contours, drainage, political boundaries and other topographic features, but also checking the positions of the houses as located by the traverseman.

While the above description of the methods employed applies directly to the work done in the more thickly settled Eastern states, where the scale adopted is 1 mile to 1 in., and the contour interval is 20 ft., it is but slightly modified for use throughout the country on the scale of 2 miles to 1 in. and with contour intervals of 50 or 100 ft.

Extensive use is made, as secondary horizontal control, of the public land surveys in the more level portions of the West, particularly in the region east of the Rocky Mountains. These surveys are first corrected by extending over them a system of primary triangulation or traverse, and connecting this with the corners and crossings of land lines. In some localities this work is not sufficiently trustworthy to be used, even when closely controlled by triangulation. In forest-covered and rough country it is often difficult to find the corners, when it becomes necessary to supplement those discovered by traverses connecting one with the other. In some regions, where the land surveys are of good quality, the corners are easily discoverable. This is the case in regions recently surveyed, or where density of settlement has necessitated the construction of roads on most of the section lines. The work of the topographers is thus reduced to the measurement of heights and sketching, no secondary traverse work or other horizontal control being necessary, as all roads, plats of towns and plans and profiles of railroads are matters of public record in the county offices.

Heights are measured by vertical triangulation based on railway levels and by the aneroid. Vertical angle lines are run on every second or third section line by the topographer, and between these his assistant sketches the topography from aneroid elevations based on the angle lines. In running the latter, distances are measured by the odometer, checked between quarter-section corners, plotted at once and scaled off from the sketch sheet. Vertical angles are read to the platforms of windmills, gables of houses and similar objects, thus dispensing with the use of rods. Sketching goes on coincidently with the measurement of heights.

The average cost of mapping Massachusetts on the scale of 1:62 500 and in 20-ft. contours was a little over $12 per square mile. This was

the first work done by the Geological Survey on this scale. Rhode Island and Connecticut were mapped more carefully and accurately at $10 per square mile. The cost depends largely on the topography of the country. Perhaps the best work yet done by this organization was the mapping of 870 sq. miles about Philadelphia in 1894. Owing to the great amount of culture, such as roads, houses, etc., this work cost $14 per square mile. In New York the best work ranges from $5 in the level country west of Rochester, to $12 in the more broken country east of the Hudson, and even as high as $22 in some parts of the Adirondacks.

In the mountainous regions of the South and in the far West, on the scale of 2 miles to 1 in. and in 100-ft. contours, the work averages $5 per square mile. In the plains country of Dakota, Nebraska, etc., where the public land surveys can be utilized, the cost averages $2 to $3 per square mile. All of the above figures include the office expenses for the winter months when the maps are drawn up.

Something is now to be said of the work of the United States Geological Survey as a whole. The organic law of 1879, creating this survey, as modified in 1882, provides that "The Director of the Geological Survey shall have direction of the Geological Survey and the classification of the public lands, and the examination of the geologic structure and the mineral resources and products of the national domain, and the preparation of a geologic map of the United States." After several years of congressional discussion, this was interpreted to include the making of a topographic map of the entire United States as a base for the mapping of the areal geology.

The scope of the work of the Geological Survey, as modified by legislation from time to time, has come to include the preparation of a topographic base map of the entire United States; the study and mapping of the areal geology upon this base; the examination of the geologic structure and resources of the national domain; the gathering of statistics of mineral production; a study of the artesian and surface water supply of the United States; the mapping of the timbered areas of the country; and, indirectly, the classification of the agricultural value of the public lands.

As in the mapping of the topography of the United States, so in the mapping of the geology. A large amount of valuable detailed work has been done by various state surveys and by the several

government surveys which made reconnoissances west of the Mississippi River. These works were all conducted independently. As the geologists of the Federal Survey had to await the preparation of the base map on which to indicate their areal work, they spent the first 10 years in bringing together the scattered results obtained by all other organizations and individuals into a comprehensive whole, and in studying the nomenclature of, and classifying, the sedimentary and volcanic rocks. The result of this work has been the assembling in systematic form of a great mass of geologic information which has paved the way for the mapping. In consequence, now that the publication of the areal map is begun, it is being pushed forward in a rapid and systematic manner.

This areal geologic map, the final product of the work of the Geological Survey, is presented in geologic folios, each of which covers the area included within a topographic atlas sheet. These folios consist, first, of a brief text descriptive of topographic and geologic maps and the uses to which they may be applied; next comes a general description of the geology of the region within which is included the folio; then a more detailed description of the geology of the area covered by the folio, which is divided into descriptions of each of the various local formations, an account of the mineral resources, and in some cases an analysis of the economic minerals included within the area. This descriptive material is followed by five maps; the first is the topographic atlas of the region; the second, called the areal geologic map, shows the distribution of the overlying rocks within its area; on the third, the economic geologic map, is shown the rocks containing minerals of economic value, these being indicated by distinctive colors; and on the fourth, or structure section sheet, the underground geology is graphically illustrated, as it is also on the fifth map, which consists of a series of columnar sections.

The scope of the work of the hydrographic division of the Geological Survey is expressed in the statute authorizing it, passed in 1894, which reads: "For gauging the streams and determining the water supply of the United States, including the investigation of underground currents and artesian wells in arid and semi-arid regions." The demand on the survey for information concerning the water resources of the country has increased from year to year. Inquiries come from all sources seeking information relative to artesian water

supply, water-power and water for irrigation. Response to such inquiries requires not only broad knowledge of the topography, geologic structure and meteorologic conditions of the regions involved, but also careful measurement of the catchment areas of the various streams and gaugings through a period of years of their discharge. Such results as have been so far secured were largely incidental to the brief irrigation survey created in 1888. Under the law passed in 1894, however, the work has been systematized and extended as thoroughly as the appropriations will permit. It includes not only an investigation of the conditions in the arid region, but also in the eastern and southern states, where such information is of great value in connection with the utilization of water-power and in the construction of canals and other waterways. A large amount of voluntary assistance is given by local observers who realize the value of the work, and by railway engineers who are sufficiently interested to have their bridge tenders read the river gauges. This co-operation renders much more extensive results possible than with the limited resources at the command of the Survey.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

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Vol. XXXIII.—May, 1895.

BACTERIA AND OTHER ORGANISMS IN WATER.

By JOHN W. HILL, M. Am. Soc. C. E.

READ APRIL 17TH, 1895.

WITH DISCUSSION.

In the operation of the filters of the London Water-Works, and indeed of all the European works where filters are used, the test of filtration is based on the number of bacteria of all kinds found in the filtrate. While numerous special examinations have been made of the kinds of bacteria remaining in water after filtration, no continuous tests or standards of efficiency based upon the varieties found have been made so far as the author is aware. Evidently if the bacteria removed are of the harmless kinds, while those that remain are of the pathogenic varieties, no great benefit can be expected from simple filtration of a polluted water. That this is not the case is well attested by the operation of the London filters, which during the past 10 years have been rated upon a bacterial rather than a chemical standard of efficiency, and have reduced the typhoid fever death rate to 14 or 15% of

the rate which prevailed before filtration was practiced. But while the reduction in the numbers of bacteria has been by the London filters from 96 to 99.9% of the original numbers in the water as shown by control plates, the reduction in the typhoid rate has been much less than this, which suggests that of the bacteria still found in the water after very careful filtration, a larger percentage are of the typhoid variety.

Considering the typhoid bacillus as among the smallest known, while many of the harmless kinds are much larger in dimensions, it can be understood how it is possible to have in the filtered water a much larger proportion of the typhoid variety than was found in the original water. In other words, while the general reduction of bacteria in the water has been 96 to nearly 100%, the reduction of the typhoid bacillus probably has been much less than this.

Having a desire to know something about the micro-organisms in the Ohio River water supplied to the city of Cincinnati, and especially upon the effect of the local domestic filters in reducing the numbers of bacteria in the water, a series of careful tests has recently been made to determine generally ;

First.—The kinds of micro-organisms other than bacteria in our local water supply.

Second.—To determine the numbers and to some extent the kinds of bacteria found in the unfiltered and filtered water.

In the examination for the larger micro-organisms, an American microscopic outfit has been used, generally with a 1-in. ocular and 1-in. and ¼-in. achromatic objectives. When nice detail of diatoms or desmids has been under examination, a ¼-in. and occasionally either a ⅛ or 1/12-in. homogeneous immersion objective has been used. However, for the simple determination of kinds and numbers of organisms (other than bacteria) the 1-in. and the ¼-in. focal length objectives have been found sufficient.

The water sample for the larger micro-organisms is collected in a small bottle provided with a filter of surgeon's cotton, the bottle connected with a tap by means of a small hose ; and, the tap being set well open, the filtration is accomplished through the cotton filter under low pressure. After the bottle has been in service from 6 to 8 hours it is removed from the tap and the remaining water again passed through a cotton plug in the stem of a 5-in. glass funnel. The cotton filter of

the collecting bottle is soaked and dabbled in the water of the funnel to remove or detach any organisms caught in the cotton filter. After the water has nearly all passed through the cotton plug in the funnel,

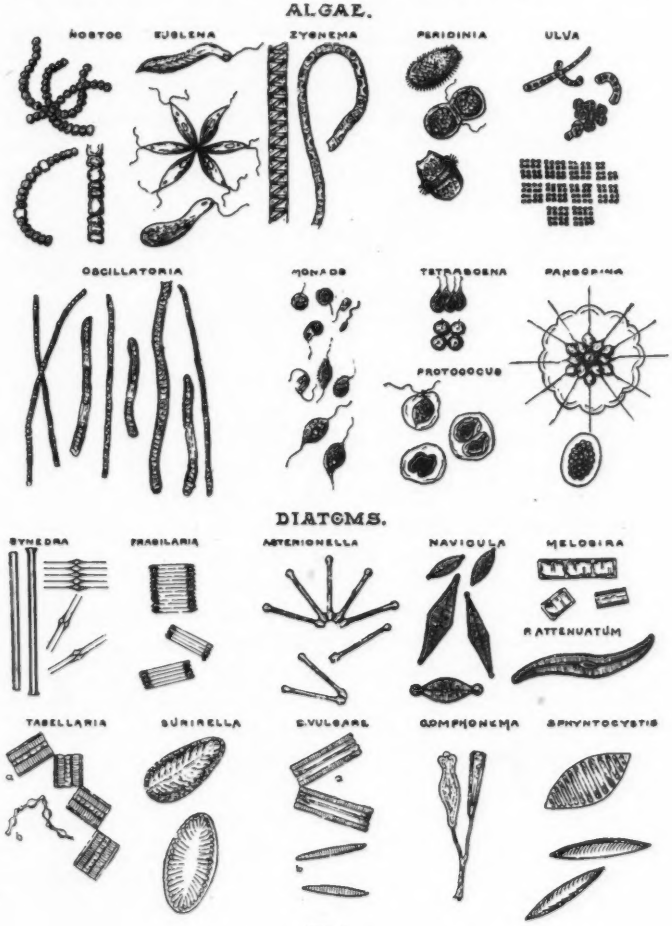

FIG. 1.

small quantities of the sediment are taken up and examined under the microscope. The cell used for this purpose is a plain glass slide

3 x 1 in. in dimensions, to the center of which is cemented a hard rubber ring, about $\frac{1}{32}$ in. high or thick, and giving an internal field of $\frac{3}{8}$ in. diameter. The water sediment is dropped from a pipette into the cell and covered with a $\frac{3}{4}$-in. No. 1 or No. 2 round cover glass.

From the simple microscopic examination of the Ohio River water the following organisms have been found :

Algæ.—(Fig. 1.) Nostoc, Zygnema, Euglena, Peridinium, Ulva, Oscillatoria, Monads, Tetrabœna, Protococcus, Pandorina.

Diatoms.—(Fig. 1.) Synedra, Fragilaria, Asterionella, Navicula, Melosira, P. attenuatum, Tabellaria, Surirella, D. vulgare, Gomphonema, Sphyntocystis.

Desmids.—(Fig. 2.) Pediastrum, Scenedesemus, Cosmarium, Staurastrum, D. Swartzii, Docidicum baculum, Spirotænia.

Infusoria.—(Fig. 2.) Keronia, Enchelia.

Rhizopods.—(Fig. 2.) Difflugia, Amœba, Euglypha, Actinophrys sol.

Rotifers.—(Fig. 2.) Hydatina senta, Monostyla quadridentata, Brachionus amphiceros.

Entomostraca.—(Fig. 2.) Bosmina cyclops, Daphnia pulex.

Spongilla.—(Fig. 2.) S. Lacustris, S. Fluviatilis.

Nematods.—(Fig. 2.) Anguillula fluviatilis.

Miscellaneous.—(Fig. 2.) Ova of Ascaris dentata, scales of insects, cotton fibers, shaft of straw, tip of feathers, amorphous matter.

Some of these organisms like Nostoc, Asterionella formosa, Oscillatoria and other of the algæ, have been charged with the production of bad tastes and odors when found in impounded waters, but such objection to their presence has never been noted in connection with the Ohio River water. Possibly the numbers were not sufficient to affect the large volume of water usually flowing in the river, or it may be that the opportunities for growth and decay are less in streams than in quiescent reservoirs.

The most objectionable, or at least the most repulsive, elements in water are the masses of albuminous matter in process of disintegration, and the infusoria and other organisms which are seen feasting on this matter. Having the amorphous or indescribable matter which may come from sewage and other organic sources, it is proper to have the infusoria, rhizopods and other primitive organisms to assimilate it, and render it less offensive to good taste, as well as less inimical to

health. But to find the slimy, crawling, leechlike creatures traveling around in water which is offered one for drinking purposes cannot be

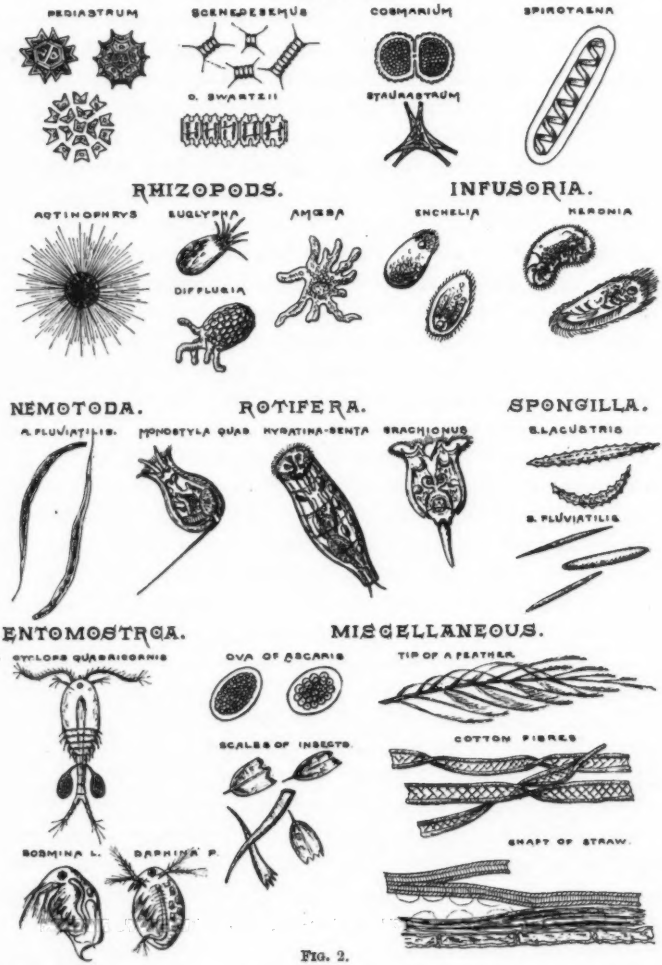

FIG. 2.

regarded as a recommendation for such water. Among these lowly organisms found in a polluted water are some in which the differentia-

tion between the animal and vegetable growths can be accomplished only by chemical tests upon the protoplasmic substance, many of the protophyta or vegetable products having the appearance and motion of animals, and many of the protozoa or animal growths having the appearance of vegetables with no apparent motion at all, or often seen at rest and indicating a state of complete repose.

In making tests for the bacteria in water, the method pursued by the author has been to collect the water in carefully sterilized 2-oz. glass-stoppered bottles, enclosed in small sterilized tin canisters, and to inoculate the gelatine or agar plates with one or more drops of the water under examination, and then, after mixing the water and melted media, heating the mouth of the tube, and singeing the cotton plug to destroy any chance organisms, to pour the solution of nutrient media and water into a sterilized Petri dish. Usually from 6 to 10 cu. cm. of gelatine or agar is used, and the number of drops of water from a sterilized pipette depends upon the extent of pollution, or rather the number of bacteria suspected in the water. From a very polluted water, one drop, or $\frac{1}{15}$ cu. cm., is too much, the number of bacteria present being so great as to be innumerable by the Wolffhugel method, and absorbing the nutrient media so completely as to prevent the growth of some varieties. In such cases, after shaking the bottle containing the sample of water under investigation, it is customary to dilute this several times with sterilized distilled water and multiply the actual count of bacteria accordingly. With comparatively pure natural waters (which are, unfortunately, rarely found) $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$ or 1 cu. cm. is used for inoculation purposes; a single drop from one of the ordinary dropping tubes or pipettes with rubber tops may contain from $\frac{1}{12}$ to $\frac{1}{24}$ cu. cm., and after the use of one of these it must be measured to determine the proportion of a cubic centimeter used in the inoculation. The period of incubation which has been allowed is five days at room temperature, except with filtered waters, when the time has been extended from 10 days to two weeks or more. The growth of bacteria is rapid in polluted water, and if liquefying organisms are present, as they generally have been in the waters experimented with, the count must not be delayed beyond four or five days or the liquefiers will spread over the plate and obscure some of the non-liquefying colonies. It is a noticeable fact in the author's experience, that plates inoculated with water from the best type of filters require more

time for the incubation of the colonies of bacteria than those with unfiltered water. Thus the germs left in the water after filtration grow at a slower rate than many that are in the water before filtration. From which it would follow that in counts of plates of unfiltered water at the end of a few days, some bacteria are very liable to be overlooked because they have not grown. This may have no significance, but it is well known that the typhoid bacillus is comparatively a slow growing germ, and might be obscured on an ordinary growing plate. While the growth of many of the bacteria is much slower at room temperature subject to variations, than in the incubator where the temperature is maintained quite constant, still the rapid-growing liquefying germs in the incubator are frequently seen to spread and obliterate the non-liquefiers, and destroy the germs of slow growth altogether.

From the bacterial examination of water supplied through the public mains of Cincinnati, the following results have been obtained.

Samples of water freshly plated:

1894. Plate Inoculated.	Plate Counted.	Colonies of bacteria per cubic centimeter of sample.
July 14th,	July 18th,	9 570 (*a*)
July 14th,	July 18th,	7 665 (*a*)

Same sample of water tested 10 days after collection in sterilized bottle:

July 24th,	July 29th,	163 000 (*a*)
July 24th,	July 29th,	94 050 (*a*)

Sample of water freshly plated:

August 1st,	August 6th,	1 680 (*a*)
October 5th,	October 10th,	1 872 (*b*)
October 5th,	October 10th,	5 820 (*a*)
October 24th,	October 29th,	1 760 (*b*)
November 2d,	November 7th,	2 674 (*a*)

(*a*) Gelatine, 10% solution, water in bottle shaken.
(*b*) Agar, 1% solution, water in bottle shaken.

Water from the local filters has given the following results. Pasteur filter in perfect condition :

1894. Plate inoculated.	Plate Counted.	Colonies of bacteria per cubic centimeter of sample.
July 16th,	July 23d,	52 (*a*)
October 5th,	October 10th,	2 (*a*)
October 5th,	October 15th,	4 (*a*)
October 5th,	October 15th,	4 (*b*)

Pasteur filter in drug store furnishing water for prescriptions:

November 6th,	November 25th,	4 (*a*)
November 6th,	November 25th,	8 (*a*)

Pasteur filter in ordinary condition:

October 5th,	October 10th,	974 (*a*)
October 5th,	October 10th,	1 536 (*a*)
October 5th,	October 10th,	580 (*b*)

Pasteur filter, well taken care of in one of the leading hotels, supposed to be sterilized every two or three days:

October 24th,	October 29th,	436 (*b*)
October 24th,	October 29th,	180 (*c*)
October 24th,	October 29th,	209 (*c*)

Derham's stone germ-proof filter, in a popular restaurant:

August 27th,	September 2d,	19 035 (*c*)
August 27th,	September 2d,	48 600 (*a*)

Freudenrich* has made some experiments with the Pasteur filter to determine the sterility of the filtrate at different dates after sterilization of the tubes, and for different temperatures of the room in which the filters were kept, and finds that at a temperature of 35° Cent. the filter delivered sterile water at the end of six days, while at a temperature of 22° Cent. the filtrate in some cases was, and in other cases was not, sterile at the end of 10 days. The cause of one filter furnishing sterile water and another operated under the same conditions giving a filtrate containing bacteria, is explained by the investigator as being due to the difference in the density or porosity of the

(*a*) Gelatine, 10% solution, water in bottle shaken.
(*b*) Agar, 1% solution, water in bottle shaken.
(*c*) Gelatine, 10% solution, water in bottle not shaken.
* *Centraiblatt fur Bacteriologie*, Vol. XII, 1892, p. 240.

tubes, and to differences in the micro-organisms present in the water at different times.

It has been the author's experience with water from filters of this type that they never furnish absolutely sterile water; for upon a series of plates inoculated with such water, while some may remain sterile for several days, in due time they will develop one or more colonies. An entirely sterile plate he has never met with. Professor Percy Frankland, in discussing this filter, says: "It must be regarded, therefore, still as an open question whether pathogenic organisms, such as typhoid bacilli, can or cannot grow through the pores of the Chamberland (Pasteur) filter, and until this question has been answered in the negative, it is obvious that in using these cylinders they should be frequently cleaned and sterilized." Not having the details of the Freudenrich tests, it is impossible to compare the results from abroad with those obtained here. Tests of Pasteur filters in such condition as they are found in hotels and restaurants have given from 180 to 1 500 bacteria per cubic centimeter, and the low counts of two to four bacteria per cubic centimeter have been obtained from tubes not previously used.

During August, 1894, some bacterial tests were made of the water supplied to Jersey City, N. J., with the following results:

Plates inoculated.	Plates Counted.	Bacteria per cubic centimeter.
August 19th,	August 24th,	1 560 (*c*)
August 19th,	August 24th,	1 575 (*d*)
August 19th,	August 24th,	9 918 (*a*)
August 19th,	August 24th,	9 390 (*b*)

Water from a well-known sand filter found in one of the Jersey City hotels:

August 19th,	August 24th,	8 295 (*b*)

A sample of Jersey City water gave the following results:

August 14th,	August 21st,	1 200 (*d*)
August 14th,	September 1st,	125 000 (*d*)

Note the last result, a count of the plate after one week's inoculation gave on agar 1 200 colonies. The plate was then returned to the moist chamber, and at the expiration of 18 days from the date of planting, it showed, when counted, an increase of over 100 to 1 of the

(*a*) Gelatine, 10% solution, water in bottle shaken.
(*b*) Agar, 1% solution, water in bottle shaken.
(*c*) Gelatine, 10% solution, water in bottle not shaken.
(*d*) Agar, 1% solution, water in bottle not shaken.

bacteria found at the end of seven days. A portion of this latter number probably came from the air of the room in which the work was conducted, but from a number of tests at different times on air plates, the rate at which the air germs and molds fall into a 3¼-in. Petri dish is from three to four per minute of exposure, and as the exposure of a growing plate to contamination by air germs is carefully limited to the least possible time, but few of the 125 000 colonies of bacteria in this case could have gravitated from the air into the dish.

Professor Percy Frankland* has made many bacterial tests of the waters of the Rivers Thames and Lea before filtration, with the following results for the same months as were embraced in the author's tests of water from the Ohio River:

RIVER THAMES—BACTERIA PER CUBIC CENTIMETER,

MONTH.	1886.	1887.	1888.
July	3 000	2 500	1 070
August	6 100	7 200	3 000
September	8 400	16 700	1 740
October	8 600	6 700	1 130
November	56 000	81 000	11 700

RIVER LEA.—BACTERIA PER CUBIC CENTIMETER.

MONTH.	1886.	1887.	1888.
July	5 400	12 300	2 190
August	4 300	5 300	2 000
September	3 700	9 200	1 670
October	6 400	7 600	2 310
November	12 700	27 000	57 500

Later bacterial tests of waters from the same sources by Dr. E. Frankland† have been made as follows, taken for the same month as before:

RIVER THAMES.—BACTERIA PER CUBIC CENTIMETER.

MONTH.	1892.	1893.
July	2 263	2 132
August	2 421	1 895
September	947	1 158
October	2 316	13 790
November	1 868	1 789

* "Micro-Organisms in Water," by P. and G. C. Frankland, 1894.

† Annual Summary of Vital Statistics, in London, etc., 1892-93.

RIVER LEA.—BACTERIA PER CUBIC CENTIMETER.

MONTH.	1892.	1893.
July	631	8 816
August	631	6 658
September	737	3 658
October	737	5 368
November	3 183	8 026

The agreement of the numbers of bacteria in the water of the River Lea upon two occasions for two consecutive months is very remarkable, and suggests a bacterial condition of the water which the author has never before noticed in any experiments.

A comparison of the bacterial condition of the raw water supply of London for the years 1892–93, with the earlier results obtained by Professor Percy Frankland, shows a very marked improvement in the quality of the water.

The general standard of bacterial quality of the filtered London water is 100 per cubic centimeter, but according to Dr. Frankland, there would be no difficulty for some of the companies to keep the number under 50 per cubic centimeter in the filtered water. The advantage of frequent bacterial examinations of a water supply is well stated by this authority* in the following quotation :

"The vast majority of microbes found in potable waters are, as far as is known, entirely harmless, and although pathogenic germs have been discovered amongst these, it has only been on rare occasions. They have never been observed in any water supplied to London, but it must not, on this account, be concluded they are never present. * * * A glass of water might contain two or three typhoid germs, and yet it would only be by the merest chance that one of them would be included in the five-hundredth part of the glassful (half a cubic centimeter) taken for bacteriological examination."

Speaking, then, of the work of the filters of the West Middlesex Company, which were reducing the numbers of bacteria in water by 99.83%, and of the Lambeth Company, which were filtering out 98.76% of the bacteria originally in the Thames water, he says :

"In this enormous reduction there is obviously a considerable, though by no means absolute, guarantee that pathogenic organisms, if present, would disappear with the crowd. Nevertheless, it is only by the rejection for dietetic purposes of water polluted by ex-

* Annual Summary of Vital Statistics, in London, etc., 1891, p. 51.

crementatious matters that immunity from water-borne zymotic poisons can be secured."

It is not practicable to reject water containing sewage pollution in all cases of a public water supply, but it is practicable to sterilize all such waters before they are used for dietetic purposes.

Many tests of the waters of the River Spree and Lake Tegel supplying the city of Berlin, have been made by Plagge and Proskauer*, with the following results for the year 1885:

BACTERIA.—PER CUBIC CENTIMETER.

MONTH.	RIVER SPREE.	LAKE TEGEL.
July	2 640	1 500
	110 740	13 220
August	1 800	179
	11 900	4 410
September	960	111
	9 200	1 220
October	1 204	160
	4 840	519
November	2 520	60
	31 500	251

The sewage pollution of the Thames River, above Hampton Court, and of the River Lea, above New River cut, or of the River Spree, above Berlin, is probably much less than that of the Ohio River above Cincinnati; here the river is said to carry the sewage of 1 500 000 people before it passes the city intake, and while the bacterial condition may appear to be better than that of London (1886–1888) and the Berlin supply from the River Spree (1885), there can be no doubt of the greater probability of finding pathogenic germs at all times in our water supply. Few consider that our water supplies when taken from the Great Lakes and rivers carry into our households the refuse from hospitals, asylums and many other public institutions where infectious disease generally is prevailing. Of such institutions there are many on the Ohio River and its tributaries above Cincinnati.

The great variation in the numbers of bacteria counted from the same source on different dates of the same month, or upon a series of plates all inoculated in the same manner at the same time, has frequently been noted, and is probably due primarily to the lack of

* Zeitschrift für Hygiene, Vol. II, 1887, p. 401.

uniformity in the distribution of the bacteria throughout the water sample, and somewhat to the nutrient properties of the media employed and temperature of growth.

When the nutrient media are from the same solution for a series of three or more plates, and the conditions in other respects the same, the author has frequently found a great difference in the number of bacteria from successive drops of water from the same sample, which can be reconciled only upon the theory of a lack of uniform distribution of the organisms in the water sample. It is well known in the case of a water sample allowed to stand for a few minutes, that the number of organisms varies considerably with the depth at which they are taken by the dropping tube, the smaller number being found near the surface of the water, and the larger number at the bottom. To avoid an error due to depth of water when the sample is taken up for inoculation of the nutrient media, it is customary to shake the bottle thoroughly before it is opened and the sample taken, to distribute as well as possible the organisms throughout the whole volume of water.

The number of bacteria per cubic centimeter of a water sample also depends upon how the inoculation is made; whether the water is taken from the collecting bottle and quickly dropped into the gelatine, or is given time to permit of the bacteria settling to the point of the pipette before inoculating the tube. A test for the effect of gravitation of the bacteria after the sample of water has been taken up in the dropping tube is given below:

Plate I.—Water taken from the beaker into the tube, and a few minutes allowed for the bacteria to settle to the point of the tube before the inoculation was made.

Plate II.—Inoculation quickly made after the sample of water was taken into the dropping tube.

Plate III.—Same as 2.

WATER FROM DOMESTIC CISTERN.

Plate I.—Bacteria per cubic centimeter	1 330
Plate II.—Bacteria per cubic centimeter	460
Plate III.—Bacteria per cubic centimeter	480

In regard to the use of round numbers in stating the count of a plate containing a growth of water bacteria, it is proper to remark that

in most cases great exactness in the count is not necessary. It is quite immaterial whether the count of a given plate is 1 500 or 2 000 bacteria per cubic centimeter, because either number is many times in excess of the standard now set for potable waters. Moreover, those who have had experience in counting the growth of a large number of bacteria by means of the ruled glass plate set over or under a deep Petri dish can well understand how easy it is to under or over count the number by a small percentage.

The question is sometimes asked of what advantage is the knowledge of numbers of bacteria in water? To which the answer may be given that numbers indicate sewage pollution. Large numbers have not been found in waters from exceptional sources, as springs, deep wells, hail, and freshly fallen rain and snow, and the numbers increase per unit of volume when we approach those sources known to be sewage polluted until we reach veritable sewage, when the numbers become uncountable excepting by such a large dilution of the sample as to leave the resultant count a broad guess as to actual numbers. Taking the extremes of deep well water with very few bacteria, and sewage with millions per cubic centimeter, we can readily conceive of a tolerably intimate connection of numbers and organic pollution in a source of water supply, and in the absence of proof to the contrary it is proper to infer that in a water known to be open to sewage contamination and showing large numbers of bacteria it is very possible that pathogenic germs are among the lot.

Apollinaris water is regarded everywhere as the "Queen of Table Waters," and is in such demand for drinking purposes that in our country it commands a price of from 75 cents to $1 per gallon, a very high price indeed for even an absolutely pure drinking water. Recognizing the extent to which this water is used for drinking purposes and having a curiosity to know more about it, the author recently made three plate cultivations on gelatine from a fresh unopened bottle of Apollinaris water, with the following results:

Plate I.....	1 984	bacteria per cubic centimeter.
Plate II.....	1 728	" "
Plate III.....	2 112	" "

The standard for the filtered water from the London Water-Works has been stated as 100 bacteria per cubic centimeter, and the number

has often been so low as 18–20 per cubic centimeter, and upon one occasion absolutely sterile water was reported.*

Before inoculating the gelatine with the Apollinaris water, great care was taken to heat the neck of the bottle and scorch the cork before the wires holding it in the bottle were cut; and everything being in readiness, the inoculations were quickly made.

While the number of germs in the Apollinaris may be more or less (probably less by the inhibiting action on the growth of bacteria of the "carbonic acid gas" in the water) than when originally bottled, still this is the condition in which we drink it when taken from freshly opened bottles. Among the organisms found on the gelatine plates was *Cladothrix dichotoma*, which is usually held to indicate the presence of considerable organic matter in water. The water reacted quite alkaline, and it would therefore be good breeding material for most water bacteria, especially the cholera bacillus.

The spring from which this well-known water is obtained is located in the valley of the Ahr, in Rhenish Prussia, and is said to have a capacity of 27 400 U. S. galls. per day, while the present output of bottled water amounts to 12 330 galls. per day. A number of chemical tests have been made of Apollinaris, but from the information available it seems not to have been tested for bacterial life before.

From tests of water samples taken from the Ohio River at Cincinnati and other sources, a few germs have been carefully differentiated as given in the following list.

In some cases there is doubt in the author's mind of the germs being correctly designated, but the slight difference between the appearance under the microscope and otherwise of a number of the water bacteria which have been described leaves room for suspicion that some of the descriptions of independent and different germs are really of varieties of the same growth, and while several of the germs mentioned below may be totally new growths, as they have sometimes appeared to be, the author prefers to fit them as well as possible to the descriptions given in the old lists of bacteria found in various waters. Unless the exact culture methods of the original investigators are fol-

* Annual Summary of Vital Statistics for London, etc., 1893. Chelsea Company for February, p. 55. The author is disposed to take this statement with some allowance. While of a series of three or more dishes inoculated at the same time from the same sample of filtered water, some have failed to develop any growth within the customary five days, as an average of all the dishes he has never had a wholly negative result.

lowed, certain differences in color, form and luxuriance of growth and microscopic appearance of the bacteria will occur, which renders the differentiation of the growth by any of the existing lists at times a very perplexing task. However, if in all cases the differentiation be carried far enough to determine non-pathogenic properties, from a water analyst's standpoint it is immaterial what the precise designation of the germs may be.

Bacteria Found in the Ohio River Water.

Bacillus hyalinus.—Originally described by Mr. Edwin O. Jordan, Report of the Massachusetts State Board of Health, 1890. From the sand of a tank used for filtering sewage.*†

Bacillus der rothe.—Originally described by Lustig, "Diagnostik der Bacterien des Wassers," 1893. Found on one occasion in river water.*

Bacillus liquefaciens.—Originally described by Eisenberg, "Bacteriological Diagnosis," 1887. Frequently found in water.* † ‡

Bacillus fulvus.—Originally described by Zimmerman, "Die Bacterien unserer Trink und Nutzwasser, inbesondre des Wassers der Chemnitz Wasserleitung," 1890. Found in Chemnitz water supply.*†

Bacillus figurans.—Originally described by Dr. V. C. Vaughan, in "A Bacteriological Study of Drinking Waters," 1892. Found in several Michigan waters.†

Bacillus violaceus.—Originally described by Zopf, *vide* "Die Mikro-organismen," 1886. Found in water and hail.* † ‡

Bacillus subtilis.—Originally described by Ehrenberg. Found in air, water, fæces and putrid liquids.* † ‡

Micrococcus carneus.—Originally described by Zimmerman, in an examination of the Chemnitz water supply mentioned above.* †

Micrococcus rosettaceus.—Originally described by Zimmerman, in an examination of the Chemnitz water supply mentioned above.* †

Micrococcus aquatilis.—Originally described by Meade Bolton, "Zeitschrift für Hygiene," Vol. I, 1886. Very frequently found in water.* †

Micrococcus cereus albus.—Originally described by Passet (see below).* †

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* Micro-Organisms in Water, by Percy and G. C. Frankland, 1894.
† Manual of Bacteriology, by Dr. George M. Sternberg, 1892.
‡ Bacteriological Diagnosis, by Dr. James Eisenberg, Vienna, 1887.

Micrococcus citreus.—Originally described by Adametz, "Die Bacterien der Nutz und Trinkwasser," 1888. Found in water.*

Vibrio aureus.—Originally described by Weibel, "Centralblatt für Bacteriologie," Vol. IV, 1888. Found in a sample of sewer mud.* †

Bacteria Found in Apollinaris Water.

Micrococcus cereus albus.—Originally described by Passet, "Fortschritte d. Medicin," 1885, No. 2. Found in pus by Passet, and in water by Tils; occurs also in air.* †

Sarcina candida.—Originally described by Lindner, "Die Sarcinie-organismen der Garungsgewerbe," Berlin, 1888. Found in the water supply of a brewery; occurs also in the air.* †

Cladothrix dichotoma.—Originally described by Cohn. Present in large numbers in fresh and brackish waters, and in both running and stagnant water, especially in the latter when rich in organic material.* †

Bacteria Found in Cistern Water.

Bacillus aquatilis.—Originally described by Lustig, "Diagnostik der Bacterien des Wassers," 1893. Found frequently in various waters.* †

Bacillus aureus.—Originally described by Adametz, "Die Bacterien des Nutz und Trink Wassers," Vienna, 1888. Found in water and on the skin of eczema patients.* †

Bacillus fluorescens liquefaciens.—Originally described by Flugge, "Die Mikro-organismen," 1886. Very often found in water.* †

Micrococcus aurantiacus.—Originally described by Schroeter, "Beitrage z. Biologie der Pflanzen," 1870. Found in water and in the air.* †

Incidentally the following organisms have been found in the air of the room where the work has been conducted. Frequent tests have been made upon the air, to arrive at possible contaminations upon plates and in test tubes, when of necessity these are exposed to the atmosphere.

Bacillus ramosus.—Originally described by Percy and G. C. Frankland, "Zeitschrifte für Hygiene," Vol. VI, 1889. Found in the soil and in water (heretofore).* †

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* Micro-Organisms in Water, by Percy and G. C. Frankland, 1894.
† Manual of Bacteriology, by Dr. George M. Sternberg, 1892.

Micrococcus versicolor.—Originally described by Flugge, "Die Mikro-organismen," 1886. Frequently found in the air; also in water.* † ‡

Micrococcus candicans.— Originally described by Flugge, "Die Mikro-organismen," 1886. Found in air and water.* †

Micrococcus carneus.—Mentioned above as having been found in the Ohio River water.* †

Micrococcus flavus liquefaciens.—Originally described by Flugge, "Die Mikro-organismen," 1886. Found in water and air.* †

Micrococcus cerasinus siccus.—Originally described by List, "Die Bacterien des Nutz und Trink Wassers," Vienna, 1888. Found in water (heretofore).*

Sarcina lutea.—Originally described by Schroeter, in "Beiträge z. Biologie der Pflanzen," Vol. I. Found in air and water.* † ‡

None of these bacteria are said to have pathogenic properties.

A careful investigation of the subject of bacteria in a water supply seems to lead to the following conclusion: If the source of water supply is beyond the reach of sewage contamination, the probability of finding pathogenic bacteria in such water is very remote, because the bacteria of which we stand in awe, the typhoid and cholera germs, are not indigenous to water, but are always imported into it, generally from sewage sources. Upon the other hand, if the water source be exposed to sewage contamination, and bacteria are found in such water it should promptly be condemned for drinking purposes. It is a singular fact that in several instances where pathogenic bacteria have been found in water (excepting, of course, sewage effluents), the number of bacteria of all kinds per unit of volume of the water is small. Thus, Dr. Vaughan,§ in a well water containing so few as 20 bacteria per cubic centimeter, has found germs fatal to the lower animals, and presumed from collateral evidence to be pathogenic to man, while lake water from the same locality containing 5 300 bacteria per cubic centimeter was harmless when inoculated into the lower animals. Again, artesian well water containing only 10 germs per cubic centimeter was fatal to the lower animals, while river water from an adjoining county containing 3 000 bacteria per cubic centimeter was harmless.

* Micro-Organisms in Water, by Percy and G. C. Frankland, 1894.
† Manual of Bacteriology, by Dr. George M. Sternberg, 1892.
‡ Bacteriological Diagnosis, by Dr. James Eisenberg, Vienna, 1887.
§ A Bacterial Study of Drinking Water, by Dr. V. C. Vaughan, Ann Arbor, 1892.

In some tests of water samples for the city of Rochester, N. Y., made several years ago by Dr. H. C. Ernst, of Harvard,* the one which contained the fewest bacteria gave the largest variety, and was the only sample said to contain the typhoid bacillus. A statement, therefore, that by a certain process of purification the number of bacteria in a given water has been reduced from 1 000 to 4 per cubic centimeter is not convincing proof of the capacity of such process to eliminate disease germs, because four bacteria per cubic centimeter mean upwards of 1 000 in a single tumbler of water, and among 1 000 bacteria left in any sewage-polluted water there is a possibility that some may be pathogenic germs, provided such were in the water before treatment.

In one aspect of the problem, the number of bacteria in a water sample is of little consequence, because, if it is certain that there are no pathogenic organisms among the lot, no harm can possibly result from the swallowing of a few thousand or even a few million of bacteria with a glass of water. For, even if we drink absolutely sterile water, thousands of harmless bacteria from the buccal cavities are washed into the stomach with every glassful (Sternberg). The condition, however, is materially altered when we realize that in waters which have been polluted with sewage there are always grounds for a strong presumption that among the swarms of bacteria some are possessed of pathogenic properties, and in drinking such waters we are liable, in fact bound, to imbibe some of them.

In making a series of culture plates from a particular water sample the author has noticed (especially when the inoculations have been made with one or a few drops of water) that certain organisms will be found on one plate and not be found on the others, showing that while *B. Subtilis*, for instance, was present in one sample drop, it was not present in all, from which the inference is drawn that only from many tests at different times of the same water can the kinds of bacteria in such water be properly stated. One reason why pathogenic germs have been found in waters containing comparatively few bacteria per cubic centimeter, and not found in samples showing much larger numbers, is because of the easier differentiation of the kinds of bacteria when the numbers are low and the great difficulty of differentiation of all

* Annual Report of Executive Board, City of Rochester, N. Y., April, 1890.

the kinds when the numbers are high, and also in the crowding out and total obscuration of many kinds (some of which may be pathogenic) in a cultivation containing many liquefying colonies.

To some people the communication of disease through an infected water or a water carrying pathogenic bacteria seems to be mysterious, and because it does not come in some tangible form, they are disposed to doubt the transmission of infectious disease by this means altogether, and of those who recognize danger in polluted water few are aware of the number of germs known to be pathogenic to man or animals which have been found in drinking waters, some of which were not suspected of being the carriers of infection.

In Eisenberg's * list of bacteria possessing pathogenic properties 12 kinds are described which have been found in water. Dr. Sternberg † gives a list of 16 pathogenic bacteria found in water; while Professor Frankland ‡ enumerates 23 species of such bacteria found in water. Of these the most formidable are the germs of cholera and typhoid fever, and as cholera rarely visits this country, typhoid is the principal pathogenic bacteria with which we have to deal.

The mass of evidence on the cause of typhoid fever abroad and in this country is to the effect that it is invariably a water-carried disease, and in those epidemics where milk, butter, etc., are the immediate distributors of the germ, water used in connection with the dairy or in culinary operations has been the original habitat of the typhoid bacillus, from which it follows that if the typhoid germ is kept out of our dietetic water supplies, typhoid fever would cease to exist.

The author expects this statement to be disputed by some investigators, but he is not aware of any proof that typhoid fever can have existence after our domestic waters have been rendered sterile, or are known not to furnish a home and means of transportation for the bacillus.

The germ comes into our drinking and domestic waters from a sewage source; the alvine discharges of one sick with typhoid fever are run into the sewers or deposited in a domestic privy vault or on the surface of the ground, and by subsoil and surface drainage, or by air currents, are carried into the rivers, lakes and ponds, upon which as communities we rely for our daily supply of water. From the water,

* Bacteriological Diagnosis. By Dr. James Eisenberg, Vienna,, 1887.

† Manual of Bacteriology. By Dr. George M. Sternberg, New York, 1892.

‡ Micro-Organisms in Water. By Percy and G. C. Frankland, Dundee, 1894.

the germ is taken into the human system again, and, if a nidus is found in the intestinal canal, the germ establishes itself, propagates by fission, elaborates its poison (*typho toxin*), and the ulceration of the Peyer's patches, and other symptoms of typhoid fever are established.

Thus the life history of the typhoid bacillus may be stated: *First*, as a residence during the early part of typhoid or typho-malarial fever in the human intestine; *second*, the transfer of the fæces containing the bacilli through the water-closet and sewer, or subsoil, or surface drainage, from the premises where typhoid is prevailing to the river or other point of discharge of the sewage or drainage; *third*, a residence in the water of the river, lake, pond or reservoir (as at Plymouth, Pa., 1885), and, *fourth*, finally back again into the human system through the drinking of the water containing the germ, or through the use of an article of diet which has been brought in contact with the typhoid-infected water.

The human intestine, the liver, spleen and mesentery gland is the normal habitat or residence of the typhoid fever germ (*typhi abdominalis*). Here it finds the surroundings most favorable to its development, and from the spleen or other organ of one dead of typhoid is obtained by inoculation of a gelatine tube the minute organism which is held to be the cause of this dreadful plague of modern times. The typhoid bacillus when taken from a gelatine culture is a straight rod with rounded ends, about $\frac{1}{15000}$ in. long, and generally one-third of this in width and thickness. If one can imagine a link sausage as small as this he will have a fair idea of the shape of the bacillus. It consists of the lowest kind of living matter, protoplasm within a cellulose envelope; it forms no spores nor seeds, and propagates by fission; that is, by the elongation of the cell or rod and a division in the middle into two cells or rods, each of which again divides into two rods, and so on indefinitely.

Thus one germ or one of these little rods, of which it takes 15 000 placed end to end to make 1 in., may, under favorable conditions, become the parent of millions within a few days or weeks. It is not a rapid-growing germ, like the germ of cholera, for instance, which will fully develop in 24 hours, but grows slowly, requiring in artificial media at room temperature from a few days to two weeks to attain its normal condition of growth.

It is not a hardy germ, excepting in its ability to resist a slight

acidity in its nourishing medium, but other germs are known to have a greater resistance to acid solutions than the typhoid germ. It is an exceedingly difficult germ to differentiate or demonstrate, because in microscopic appearance quite a number of harmless (or supposed at the present time to be harmless) bacilli resemble it so closely that the difference between the several kinds of germs when grown in the same solution is usually less than the differences between the typhoid germ itself at different times from different culture materials. In its growth on gelatine, agar and potato, the favorite materials for the cultivation of all but the nitrifying bacteria, it resembles several other bacteria so nearly that differentiation from its simple growth on these materials, even when taken in connection with its microscopic appearance, is quite impossible.

At this point it is well to note that notwithstanding the many earnest attempts to successfully demonstrate the typhoid bacillus in water, etc., considerable doubt surrounds the results of all such investigations at the present time, and methods which a short time ago were supposed to be infallible in the differentiation of the germ have been shown by later tests to be wholly unreliable. Thus, the growth on sterilized potato, which at one time was regarded as characteristic of the bacillus, is now known not to be uniformly consistent, and other germs give quite the same appearance as typhoid when grown on potato.* The number of cilia or flagella has been regarded in Germany as an important element in the differentiation of the typhoid bacillus, but the author has been unable to demonstrate the flagella from growths of an imported (Berlin) germ, and others in Cincinnati who have attempted to show the cilia have been rewarded with negative results. The English tests† and the tests of the Massachusetts State Board of Health, as these are understood by the author, do not involve the demonstration of the cilia on the bacillus as an element in the differentiation of the germ. The growths in an acid solution are open to grave objections, as shown by the extensive investigations of Dunbar‡ and others, and altogether the demonstration of the typhoid bacillus in water, etc., may be still regarded as surrounded by some doubt. The author's method is to carry forward at the same time under the

* Differentiation of the Typhoid Bacillus. Annual Report Massachusetts State Board of Health, 1891, p. 637. By Geo. W. Fuller.

† Micro-Organisms in Water. By Percy and G. C. Frankland, 1894, p. 267 *et seq.*

‡ Zeitschrift f. Hygiene. Vol XII, 1892, p. 485.

same conditions of media and temperature, growths of the bacillus taken from the spleen of a typhoid subject, and of the suspected germ found in water, and if the results of microscopic examination, appearance on gelatine and agar plates, and in gelatine and agar tubes, and in the acid reaction in sterilized milk are the same for both growths, then to turn the supposed typhoid growth over to a medical friend for observation of the symptoms from inoculation tests on the lower animals.

Several methods of differentiation are now known which, in skillful hands, will enable one to form a fair judgment on the presence of this germ in a suspected water or article of diet. But the decisive test is to be had only by many carefully conducted inoculations of the germ into the animal system.

This is the germ of Eberth, found in the spleen of a typhoid fever subject, and germs resembling this in all outward respects have frequently been found in drinking water, inoculations of which into dogs, cats, rabbits and guinea pigs have been followed in many cases by death within a day or two, after a series of symptoms resembling somewhat the typhoid symptoms in man. Inoculation tests, of course, have never been made upon man, and, until this has been done, the final proof of the etiological relation of this germ to typhoid fever will be wanting (Sternberg), but all the evidence of the past 13 years clearly demonstrates the Eberth bacillus as the cause of typhoid, and all the investigations of typhoid epidemics as clearly indicate an infected water (or milk or other article of diet infected from water) as the carrier of the germ or cause of the disease.

For drinking and other dietetic purposes every community, in fact every household, should have a sterile water. A sterile drinking water cannot be found in Nature (hot springs and geysers not being regarded as sources of drinking water), the use of which will avoid the introduction into the human system of the germs of disease, and especially of typhoid fever. Water that contains no pathogenic bacteria and which is above or beyond the influence of sewage pollution can be found, but, unfortunately, seldom where it can be made available for a city supply.

DISCUSSION.

Mr. Harris. ROBERT L. HARRIS, M. Am. Soc. C. E.—A series of experiments was made in Providence, R. I., in 1893 and 1894, lasting 12 to 15 months, and an exhaustive report on the results was made to the city. This report indicates that mechanical filters act on bacteria.

Mr. Hering. RUDOLPH HERING, M. Am. Soc. C. E.—It is stated that the Providence experiments to which Mr. Harris referred have revealed nothing new. It is claimed by several parties interested in artificial filtration that the flocculent mass caused by the addition of alum or other coagulents settles upon the surface of a water filter, and thus strains out the bacteria.

The new filters built for purifying the water supply at Lawrence, Mass., furnish a good illustration of their apparent ability to exclude typhoid bacilli. For many years the State Board of Health of Massachusetts has recorded the appearance of typhoid fever cases in Lowell and Lawrence, and has found that a few weeks after the fever appeared in Lowell, it also appeared in Lawrence. It is supposed to be caused by the water supply, because the Lawrence supply is taken from the Merrimack River, which receives the sewage of Lowell. Since the filters were introduced in the fall of 1893, there has been another similar epidemic in Lowell, and for the first time on record it was not followed by one in Lawrence among persons drinking the filtered water, showing that these filters, which were constructed with the greatest care to secure this result, very likely did accomplish it.

The author's assertion that typhoid fever can be propagated only through drinking water is certainly incorrect. In Europe, and particularly in Germany, there is a large class of eminent men who hold another view. Physicians are divided into two classes on this subject, one holding the ground-water theory, and the other the drinking-water theory. There are some interesting diagrams of observations in Munich and Hamburg showing the deaths by typhoid fever in relation to the level of the ground-water. The correspondence between the death rate and ground-water curves is remarkable. In Hamburg the water supply is taken from the Elbe River, a tidal steam, and has nothing to do with the ground-water level, yet, when the latter rose, the typhoid fever mortality was greater, and *vice versa*. There has been no satisfactory explanation of the reason of this. Most cases of typhoid fever are propagated by drinking water infected with typhoid bacilli, but there are other means of disseminating this disease.

Mr. Dunham. H. F. DUNHAM, M. Am. Soc. C. E.—It is generally understood in this country that the water in streams is less desirable for drinking when they are very low. If they are polluted to a certain extent throughout the year, in that season when there is the least water in

them, it is the least desirable for drinking. As the lowest level of the ground-water occurs when the flow of the streams is least, it may be that this fact is an explanation of the correspondence between the curves mentioned by Mr. Hering. Mr. Dunham.

Professor A. A. BRENEMAN.—Perhaps the action of the coagulent in filtration may not be entirely understood by all; it is much like that of the white of an egg or isinglass in clearing coffee. It forms when diffused in the liquid an all-pervading web like a thin jelly, and being less movable than the liquid, it follows that whether it be allowed to settle or whether it be filtered out, it entangles the bacteria or their germs, and is a means of purification, an additional mode of action other than that of coating the surfaces of the filtering material with a viscous layer to which solid particles adhere during filtration. Mr. Breneman.

It has been suggested that the beneficent action of bacteria might not be generally appreciated. We are dying by the action of bacteria, and we are living by the aid of bacteria. It may be interesting to know that just as we have long been cultivating yeast plants and have brought beer and wine to the proper condition by this means and by excluding the wrong organisms, so at this time our butter and cheese are coming to be regulated by bacteria; the bacteria suitable for the proper production of butter and cheese have been sold commercially.

It seemed to the speaker that the pendulum is swinging too far in the direction of bacteriology. Bacteriology has not done much in showing the existence, in a given case, of a specific pathogenic bacillus in the water of a well or stream examined for domestic use. It has much to do in the testing of the efficiency of a filter by showing the relative abundance of bacteria or their germs before and after filtration. Bacteriological examination furnishes merely a presumption for or against the water, as chemical analysis does. The proportions of free or albuminoid ammonia, of nitrates or nitrites, which indicate the present or previous existence in a water of putrescible animal matter, have been shown by hundreds and thousands of water analyses on record to bear certain definite relations to the adaptability of the water for domestic use. It must not be forgotten, also, that the methods of chemical examination have their place and will always have their place; they are improving *pari passu* with the methods of bacteriology and must always be taken into account.

CHARLES E. EMERY, M. Am. Soc. C. E.—All filters may be so constructed as to have a mechanical action; for instance, screens and filtering material may take out leaves and other large floating objects which can be seen, and some of the organisms may also be removed in this way; but the jelly which finally shows itself on the filtering material is a beneficent growth and the nidus of beneficent forms of life, no matter whether of an animal or vegetable nature, all Mr. Emery.

Mr. Emery. of which should be permitted and encouraged, as they absorb and destroy pathogenic germs which are the cause of disease.

It is interesting, and in the same line of thought and investigation, to notice that some of the new schools of medicine are using a form of life producing one disease to destroy the form which produces another. There has been a fair measure of success obtained in the cure of cancer by giving the patient erysipelas. Smallpox thrives as long as the pabulum exists which will support it. In due time the particular nutriment is exhausted by the continued reproduction of the organism and the disease dies. This particular pabulum can, however, be exhausted or modified by the much less dangerous kine-pox, and thereby immunity be obtained from smallpox. It is well known that some diseases of the blood have the effect of driving out all pre-existing forms of similar disease, which may be explained on the above principle, or features of animal life may be supposed to be reproduced in miniature and the existence of carniverous bacteria assumed. In fact, it is credibly reported that the phagocytes forming part of the white corpuscles of the blood have been seen through the microscope to issue upon the surfaces of the mucous membrane in the throat and actually absorb bacilli carried upon such membranes through the air. The different tissues of the body represent various forms of life, each independent, in a sense, according to a special law, and the function of the animal extracts now in vogue depends upon the principle of making these beneficent forms of life stronger, particularly the white corpuscles, thus enabling them to carry medicine and nutriment, and destroy the germs which cause disease. It is thus seen that in the preservation of the human system and in the preparation and care of food and water to sustain it, guidance is afforded by the same rules that form the basis of strength of the community. We must protect our friends and drive out our enemies. It has been found that poison placed in a filter, while destroying many pathogenic germs, also destroys the growth which is chiefly responsible for thorough purification. The study of a water supply involves the study of many kinds of life, and it is largely by the promotion of the beneficent forms that those which are injurious are eliminated.

CORRESPONDENCE.

Mr. Sherman.

CHARLES W. SHERMAN, Jun. Am. Soc. C. E.—Before the introduction of the Sedgwick-Rafter method of collecting the larger organisms of water for microscopical examination, the biologist of the Massachusetts Board of Health had a method of filtering out the organisms which seems much simpler than that used by the author. It consists in stretching a piece of cotton cloth tightly over the tap or the end of a funnel, and allowing the water to run through it for some time. The cloth is then removed, turned inside out, and stretched tightly over the end of a glass tube. By blowing smartly through the tube many of the organisms are detached, and they are then placed under the microscope for examination.

The author seems to imply that the bacilli of typhoid fever are likely to pass through sand filters owing to their small size, while the ordinary harmless water bacteria are retained. This would undoubtedly be the case if filtration were only a process of straining, but it has been abundantly proved that this is not the case. It has been shown at the Lawrence Experiment Station that *B. prodigiosus*, a harmless species, differing very little in size from *B. typhi abdominalis*, passes through the filters in a much smaller proportion than the ordinary water bacteria. On page 455 of the Report of the Massachusetts Board of Health for 1893 is a table from which it appears that the percentages of water bacteria remaining in the effluent varied between 1.04 and 2.34, while of the applied *B. prodigiosus* only from 0.15 to 0.46% appeared in the effluent.

Like the results of a chemical analysis of water, the figures of a quantitative bacteriological examination can be taken only as indications, never as absolute results; for not only do some bacteria develop much more rapidly than others—so much so, in fact, that a plate might be entirely liquefied by one species before the colonies of another would be visible—but it is a well-known fact that there are bacteria which do not develop at all on the ordinary culture media. One of these is the nitrifying organism, which is undoubtedly present in most natural waters, probably in considerable quantities, and does not grow on gelatine. A prolonged search has failed to bring to light any data relating to the proportion of the bacteria in a water which will develop on a gelatine culture; as a mere guess, perhaps from two-thirds to three-fourths may be assumed. Without in any way disparaging the author's experience with the Pasteur-Chamberland filter, the writer would say that a few samples he has planted from such a filter, one which does not receive extraordinary care, have proved sterile in every case.

Dr. Gehrmann. Dr. ADOLPH GEHRMANN.*—The method of carrying out bacteriological analyses by the Department of Health of Chicago is as follows: The samples are collected from the pumping stations of the city in 1 gall. glass bottles closely stoppered, which are sterilized in a steam sterilizer. After the bottles are filled, they are brought immediately to the laboratory, the analysis thus being made within one hour. The portions of the samples that are added to nutrient media are removed with a small pipette from the bottle, after it has been well shaken. These pipettes are glass tubes, graduated in tenths of a cubic centimeter, and sterilized in large test tubes. The fluid in the pipette is dropped into the melted medium immediately after the pipette is filled, and plate cultures are then made. These are always made in series on gelatine and agar. The amounts of water placed in the plates are 0.1 cu. cm., 0.5 cu. cm., and sometimes 1 cu. cm., different pipettes being used in the counts. Upon the fifth day the colonies resulting are counted by using rulings upon slate placed under the Petri saucer, over which is placed a magnifying glass. If the colonies are numerous, the plate is averaged. Finally, the resulting counts of the different amounts of water are averaged, and this is taken as the number of bacteria in the sample. At the same time, 1 cu. cm. of the sample is added to bouillon containing 0.15% of carbolic acid, and the flasks are placed in the incubator for 24 to 48 hours. If clouding results, cultures from them are made again, and some of the bouillon is injected into guinea pigs and white rats, which is considered the best means for discovering pathogenic organisms.

The author's statement as to finding great variation in the numbers of the count is a fact frequently noticed in Chicago, and for this reason the cultures are made in series. The author's experiments with the dropping tube are very interesting and the Chicago Health Department will determine its further possibilities. There is no doubt but that the statement of results should be in round numbers; it is certain that the result is only relative, and that fractions do not count. As to the presence of pathogenic bacteria in the water, it is certainly one of the most difficult questions in the subject and one that even yet demands the closest study.

Mr. FitzGerald DESMOND FITZGERALD, M. Am. Soc. C. E.—Any study that is given to the subject of organisms in water used as a source of domestic supply should receive encouragement. Many years ago the writer passed through several trying periods in connection with bad tastes developed in the water supplied to the city of Boston, which is derived from lakes and artificial storage basins. These troubles were clearly traced to the large amount of organic matter in the water giving rise to abnormal growths of algæ and other organisms, and it is now known definitely that the lack of proper preparation of the bottoms of the

* Superintendent of the laboratory of the Department of Health of Chicago.

reservoirs was largely instrumental in bringing about these growths. An enormous amount of money was expended in rectifying the evil, and believing that a more careful examination of the whole subject should be made in a scientific manner, a small laboratory was erected at Chestnut Hill Reservoir for the sole use of the Water Department of the city of Boston. This laboratory has now been in operation for about five years. Samples of water from all the reservoirs and sources of supply, taken from the surface, mid-depth and bottom, are sent weekly to the laboratory and duly classified, the organisms and amorphous matter counted by a speedy method and entered in books especially prepared for the purpose. The colors and temperatures of the waters are taken at the same time, and in conjunction with chemical analyses, enable a careful watch to be kept over all changes going on and facilitate studies of the causes producing them. Already valuable data have accumulated which are of practical importance in the management of the supply and which the writer hopes will be of value to others whenever they can be properly arranged and published. Mr. FitzGerald

In the Report of the Boston Water Board for 1894, an attempt has been made to show the causes of the sudden increase in the growth of organisms in the great periods of circulation in the spring and autumn due to the overturning of the waters and the distribution of food throughout the mass.

The following is a list of the predominating organisms in Lake Cochituate, Basins 2, 3 and 4, and Chestnut Hill Reservoir, and the number (in standard units*) which they are liable to reach without becoming abnormally large.

	Lake Cochituate.	Basin 2.	Basin 3.	Basin 4.	Chestnut Hill Reservoir.
	Per cubic centimeter.	Per cubic centimeter.	Per cubic centimeter.	Per cubic centimeter.	Per cubic centimeter.
Asterionella	750	.....	400	.....	150
Melosira	500	.....	.....	.....	50
Tabellaria	800	50	800	.....	200
Synedra	250	300	250	.....	150
Stephanodiscus	200	.....	.....	.....	150
Protococcus	350	75	200	100	100
Cœlosphærium	100	.....	2 500	.....	50
Clathrocystis	150	.....	300	.....	50
Microcystis	250	.....	200	25	100
Anabæna	50	.....	200	.....	.....
Anabæna (sterile)	150	.....	.....	.....	50
Crenothrix	510	.....	.....	.....	.....
Synura	25	.....	50	.....	.....
Cyclotella	.....	50	150	50	50
Raphidium	.....	75	.....	50	.....
Chroöcoccus	.....	.....	150	.....	.....
Dinobryon	.....	.....	75	.....	.....
Trachelomonas	.....	.....	50	.....	.....

* The unit of measurement used by the Boston Water-Works for the organisms is 400 square microns.

Mr. FitzGerald The number of bacteria in the Boston water is now very low. In the distributing reservoirs it is generally 60 per cubic centimeter, and in the tap w. ter 50 per cubic centimeter.

Mr. Riffle. A. S. RIFFLE, M. Am. Soc. C. E.—The subject of water and sewage purification is a vexed one. Just so long as the people passively recognize the prescriptive rights of riparian ownership by individuals, corporations and municipalities to discharge sewage and wastes into water-courses without previously removing those impurities which are the accepted causative agents of infectious diseases, just so long will water consumers be subjected to the visitation of typhoid, cholera and other zymotic diseases.

Although the purification of sewage in this country at present may be said to be in its experimental stage, yet the results thus far have been highly satisfactory, both as regards utility and cost of operation. The system of East Orange, N. J., a combination of chemical treatment and intermittent filtration, forcibly illustrates the possibilities of sewage purification, in that an analysis of the final effluent showed water much purer than that of the Passaic River, its secondary outlet, the entire cost of operation being about 60 cents per capita per annum. Many other systems of more or less magnitude, both separate and combined, show a cost of operation and maintenance varying from 6 cents to 50 cents per capita per annum.

This moderate cost of operation, together with the possibility of employing either irrigation, filtration, or chemical treatment, or a combination of these systems, certainly invites the careful consideration of those municipalities utilizing water-courses in thickly settled districts as a means of sewage disposal. However, conditions must be accepted as they are found, and the unwholesome quality of our river water is quite certain to exist until co-operative legislative enactment deprives property-owners of the right to convert public waterways into public sewers. This being the case, it perhaps comes more within the province of this discussion to refer to those precautionary methods which will insure the removal or destruction of micro-organic life to such an extent as to render potable the polluted waters which form supplies for so many of our cities. An appalling list of 300 000 or 400 000 cases of typhoid alone each year, with a mortality of fully 10% beside the mortality from various other zymotic diseases, all having their origin undoubtedly in the pathogenic micro-organic life in water supplies, certainly calls for the careful and exhaustive biological investigation of all sources suspected of contamination. The failure of so many municipalities, especially the smaller ones, to provide for a reliable chemical and bacteriological investigation, is due, not so much to excessive frugality, as to a non-realization of its importance. It seems to be human nature, despite facts, to regard clarified water as presenting unquestionable proof of purity while it may be foul with the germs of death and disease.

In the eastern and middle states, especially in the districts of dense population, the question of water pollution becomes one of greater importance than in the Pacific states, where, in a majority of cases, absolutely pure supplies may be obtained from uncontaminated mountain streams. These conditions are beginning to disappear, however, owing to the growth of villages and cities, and the western engineer will soon be confronted with the same problem that engages the attention and skill of the eastern expert. Mr. Riffle.

A municipality which is able to obtain an adequate supply of water from a district of uncontaminated drainage at a moderate cost is indeed fortunate. A combination of these conditions is exceedingly rare. The extreme cost of a system involving a long conduit compels a vast majority of our cities to use supplies found at their doors, regardless of the quality. It is for these less fortunate localities that the present paper has the greatest value. The use of an efficient filtration plant then becomes the only alternative. Although there is much dispute as to the efficiency of the most complete filter plants to arrest the passage of the minute pathogenic varieties of bacteria, yet their utility must be in a large measure accepted, inasmuch as a large decrease in the number of cases of zymotic diseases always follows their use. A comparison of statements as to the utility and cost of operation of the various large filtration plants in operation in this country would be of interest and value. Dr. Peter T. Austen is authority for the statement that at Atlanta, Ga., a battery of 12 filters delivers 4 000 000 galls. per day at a cost of $3 83 per 1 000 000 galls. Will the author of this paper state if he is familiar with the workings of the London filter plant, whether a coagulant is used in preparing water for filtration?

DANIEL W. MEAD, M. Am. Soc. C. E.—An absolute criterion of the purity of water for domestic supplies is greatly to be desired. But unfortunately such has never been found, and from the nature of the case, never can be found. The possibility of such a criterion must depend both on the possibility of the establishment of the fact that certain data absolutely and completely demonstrate the quality of the water tested, and also that all the water, of which that tested is a sample, is essentially the same as the sample. Various data have been proposed at different times, and advocated as the desired criteria of purity, but each in turn has been abandoned or relegated to its proper position, as it has been found to be, at best, but an imperfect measure of quality. Various chemical products of organic decay have been proposed at different times, but none have been found to give more than a general knowledge of the purity of waters, and even this general knowledge depends for its value on a collateral knowledge of the history of the water so examined. The same general conditions must also hold with the biological examination of water. Such an examination will give evidence indicative of certain conditions, but it can never serve as an absolute criterion of purity. Mr. Mead.

Mr. Mead. It is well established that organic dissolution cannot occur except through the intervention of bacterial agencies. The bacteria are the cause of decay, and the results of such decay are manifest in certain chemical products. Chemistry and bacterio'ogy therefore supplement each other in the determination of the class and nature of organic matter. A great variety of bacteria seems to exist in nature, each class having distinct functions. Thus it is the function of the yeast bacillus (*Saccharomyces cerevisiæ*) to cause the fermentation which results in decomposing the sugar in grape juice, or other solutions containing sugar, and converting it into alcohol and carbonic acid. Other bacteria of the same family possess similar functions, but they vary somewhat in the methods and the results of their action. Still other bacteria have entirely different functions, developing only in their proper mediums and under favorable conditions. The various saprophytic bacteria operate on different forms of organic matter and in different ways, one point being common to all, that in their development they cause the dissolution of the matter they attack and the rearrangement of its constituents in new forms. The pathogenic bacteria differ from the saprophytic only in the fact that they attack living animal tissues, and in their development they destroy or attempt to destroy these tissues, and in so doing produce the symptoms of the diseases which, when carried to certain lengths, produce death. The saprophytic bacteria are by far the most numerous, occurring in all the water we drink, the food we eat, and the air we breathe; and they are particularly abundant wherever decaying organic matter is abundant. They are therefore found in abundance in sewage, in garbage, and in all animal filth; and if such filth is so located that it may receive the dejecta of animals having diseases of bacterial origin, pathogenic bacteria may also be present.

From these considerations it is evident that as all normal waters must contain some organic matter, so the presence of bacterial life is also a normal condition. The increase in the number of bacteria is also a fair criterion of the increase in organic matter, but it is also clear that such organic matter may or may not be from a source productive of pathogenic bacteria, and hence may or may not be objectionable. A knowledge of the natural history of the water is therefore essential in order that the source of the bacterial life may be judged. It is, of course, possible by the identification of species to class sometimes the accompanying organic matter, but this cannot be done with sufficient exactness and facility at present except in extreme cases.

It is evident that the only absolute bacterial criterion of purity or pollution is the isolation of pathogenic bacteria from the water examined, and this is only for the individual portions examined. The life history of any bacillus may be concomitant with that of any drop of water in which it may chance to be, and its absence or presence in one

isolated portion is not conclusive evidence of the same fact relative to other portions. It is therefore believed that bacterial examinations cannot be relied on as giving conclusive evidence of the purity of any water supply, but should be regarded as one of the valuable aids toward determining such facts and conditions. Neither for the same reasons can a bacterial examination be regarded of itself a sufficient determination of the completeness of the various processes of clarification of a supply known to be more or less polluted. Such an examination may show improvement or deterioration in the quality, but nothing more, unless the bacteria are entirely absent. All criteria proposed, therefore, are of value in a relative sense only. They may be considered exact in the extreme cases of purity or pollution, when the surroundings are also demonstrative of the conditions there shown, but in the limiting case where a suspected water must be used if possible, no single criterion can ever give an absolute demonstration of freedom from dangerous organic pollution. Mr. Mead.

ALLEN HAZEN, Esq.—The paper has brought out a number of interesting facts along a line which is not sufficiently understood, and in regard to which every communication must be received with interest, and can hardly fail to produce valuable results. There are, however, one or two points which have apparently escaped the author's attention, the knowledge of which will, perhaps, tend to a better understanding of some of the facts which he discusses. Mr. Hazen.

In the first place the numbers of bacteria in the London water before and after filtration do not represent the efficiency of filtration in removing bacteria, as is often, and quite naturally, supposed to be the case. It has been found repeatedly that with filters in the same, or nearly the same, condition, the numbers of bacteria in the effluents have often been nearly constant, notwithstanding very wide fluctuations in the numbers in the unfiltered water, and this fact has been so pronounced as to lead some investigators to maintain that the bacteria in the effluents do not come from the unfiltered water, but from independent sources in the under-drains or gravel of the filters. This extreme view, however, is not supported by the latest information from Berlin, Hamburg and Altona, where this question has been studied in great detail, nor by the exhaustive experiments which have been conducted at the Lawrence Experiment Station. These later results indicate that the bacteria in the effluent from the filter are ordinarily from each of two sources; a part of them come through the filters from the water filtered, and the numbers which pass in this way bear tolerably definite relations to many of the conditions of filtration, particularly to the rate and to the depth and quality of the sand, while the other bacteria have their origin in growths in the gravel or under-drains, where harmless species, which are capable of growing upon the extremely small quantities of organic matter there present, establish themselves upon

Mr. Hazen. the stones or walls of the drains and multiply and are washed off from time to time by the current of the passing water, and join those which have actually passed through the filter.

A full discussion of the causes which control the numbers of bacteria from these two entirely distinct sources would occupy too much space. Attention is called to the fact that the numbers of bacteria in the effluents from the London filters are very much greater than the numbers which there is reason to believe have actually passed through the filters, and as it is this latter number alone which is dangerous to health, the percentage of removal of bacteria, as calculated by the author, is not so great as the actual efficiency of the filters, unless it is shown that the bacteria of typhoid fever pass through filters much more freely than the kinds of bacteria in river waters. The author alleges that this is the case, citing the death rate of London as evidence, and explains the fact by the statement that the germs of typhoid fever are smaller than other species. As a matter of fact, the typhoid bacteria are not particularly small when compared with the bacteria most common in waters. Further, the passage of the typhoid germs has been experimentally investigated at the Lawrence Experiment Station of the Massachusetts State Board of Health, and it has been found that instead of their being able to pass more freely than other species, exactly the reverse is the case, and the proportion of the typhoid germs appearing in the effluents is in general much smaller than the proportion of all the bacteria.

It is also assumed by the author that all the typhoid fever in London is due to the water supply, and, in doing so, he has overlooked the fact that polluted water is by no means the only carrier of the germs. Professor Sedgwick has shown admirably in the Report of the Massachusetts State Board of Health for 1892 that this is by no means the case, but that infected milk is also an important carrier of this disease, and that the fever is carried from one person to another by direct personal contact much more frequently than is often supposed.

As a matter of fact, the death rate from typhoid fever which a city is capable of attaining with a perfectly pure water supply is not *nil*, but instead is largely dependent upon the amount of typhoid fever in the surrounding country. In parts of Germany, where the water supplies are controlled by Government and are uniformly of excellent character, the death rate from typhoid fever has gradually declined to almost nothing, while a city surrounded by districts where the disease is prevalent will have a considerable number of cases which are brought in from the surrounding country by infected milk and other means however pure the water supply of the city may be, and this will prevent its attaining so low a death rate as would otherwise be expected. This is particularly true in English and American communities on account of the large amount of travel from city to city.

Mr. Hazen.

The death rate from typhoid fever in London is considerably lower than the average for England and Wales, and there is every reason to believe that most, if not all, of the fever in London is from other sources than the filtered river-water supplies. A part of London is supplied exclusively with water from deep wells in chalk, furnishing a water which there is every reason to believe is absolutely free from infectious matter. The portion of London supplied with this water had a death rate from typhoid fever of 123 per 1 000 000 for the years 1885 to 1891, and all of this fever is supposed to be due to other causes than the water. That portion of London supplied exclusively with filtered Thames water for the same years had 125 deaths from typhoid fever per 1 000 000, or almost exactly the same as in the population supplied from the wells in chalk, which indicates strongly that the filtered Thames water was no more injurious to health than was the well water. Other parts of London are supplied with filtered water from the River Lea, or with water from two of the sources at once, and had death rates ranging from 133 to 167 per 1 000 000, but it was thought that this slight difference could be accounted for by other causes than the water supply. The Royal Commission which was appointed to inquire into the character of the water supply of London, and made exhaustive examinations in the years 1892 and 1893, was totally unable to find evidence that the London water was injurious to health, notwithstanding the alleged fact that this Commission was appointed to secure evidence that the water was unwholesome, and that a new supply from Wales should be introduced.

No large American city has a death rate from typhoid fever as low as that of London, but some of them, New York, Brooklyn, Detroit and others, have death rates very much lower than other cities correspondingly situated but with inferior water supplies, and it may be seriously questioned whether the death rates in those cities are not as low as it is possible for them to be with the amount of infection which is constantly being brought into them from neighboring cities where typhoid fever is more prevalent. But other cities have typhoid death rates which are not only above the average, but are higher than those of all the cities in their immediate neighborhood, and such rates, taken in connection with the known pollution of the water supplies, afford ample evidence of the damage which is caused by impure water, although they do not measure it, for in any such case large numbers of cases of fever contracted by the use of the polluted water result fatally after the persons have moved or traveled to other localities where their deaths may be apparent evidence of the pollution of other water supplies which may be in reality wholesome.

Mr. Fuller.

GEORGE W. FULLER, Esq.*—In looking over the paper it appears that the author is earnestly engaged in studying the problem of supply-

*Biologist in charge of the Lawrence Experiment Station of the Massachusetts State Board of Health.

Mr. Fuller. ing communities with pure drinking water. Notwithstanding these commendable efforts on his part, the paper contains several conclusions which will be questioned by sound sanitarians. In the first place, the author does not understand clearly how it can be that in London the death rate from typhoid fever has been reduced 85 or 86%, while the process of filtration removes 96 to 99 9% of the number of bacteria in the river water. As an explanation of this discrepancy, he offers the suggestion, that "while the general reduction of bacteria in the water has been 96 to nearly 100%, the reduction of the typhoid bacillus probably has been much less than this." The facts are that the removal of typhoid bacilli by filtration under normal conditions not only equals, but exceeds, the general bacterial reduction, as indicated by the percentage of removal of the number of bacteria in the unfiltered water. This statement is proved by evidence obtained in both Europe and America. The investigations at the Lawrence Experiment Station for the past four years, as detailed in the reports of the State Board of Health of Massachusetts, show clearly that it is less difficult to remove typhoid bacilli from water by filtration than those species for which water is the natural habitat. The chief reason of this, as indicated by numerous experiments, is that the typhoid germ does not grow in ordinary water or in water filters, while quite a number of the water species of bacteria multiply within the filter and appear in the filtered water.* Farther on in the paper may be found a possible explanation of the author's remarkable position with regard to the removal of typhoid bacilli by filtration. He states that typhoid fever is invariably a water-carried disease, and if the typhoid germ is kept out of dietetic water supplies typhoid fever would cease to exist. Everyone knows that pure drinking water is an extremely important factor in the reduction of typhoid fever, but the sweeping statement above cited is incorrect. Instances abound where communities are supplied with thoroughly safe public supplies of drinking water and where the death rate from typhoid fever is very low, but yet the disease is by no means eradicated. The facts are that good living and safe living require something more than pure drinking water; among other things, good drainage and sewerage, good plumbing, well-prepared food of good quality, and a close observance of the laws of personal hygiene are necessary.

In the Report of the Massachusetts State Board of Health for 1892 it will be noticed that in the report of Professor Sedgwick upon eight typhoid epidemics, four of them, representing 46% of the total number of cases, could not be associated in any way with the quality of the drinking water. These conditions are believed to be somewhat unusual, but are mentioned to show that typhoid fever may follow infected milk and personal uncleanliness as well as polluted water. In the Report of the Royal Commission on the Metropolitan Water Supply, page 67, it is stated that "every medical witness that has appeared

* See the Report of the Massachusetts State Board of Health, 1892, p. 527.

before us, whether his general feeling was favorable or unfavorable to the (London filtered) water, has told us unhesitatingly that he knows of no single instance in which the consumption of this water has caused disease." Professor Koch, one of the foremost exponents of the theory of the transmission of disease by drinking water, devotes the first page of his latest communication on cholera to refuting the statement that he is a drinking-water fanatic, or believes water to be the exclusive bearer of the disease germ. Without the presentation of further evidence, it is obvious that the author has gone too far in his zeal in the study of water supplies, and has reached a position which cannot be supported by facts. Mr. Fuller.

The writer is heartily in favor of providing communities with pure drinking water by practicable means, and realizes fully that the use of pure water, free from typhoid germs, would place the typhoid rate of many American cities far below the present rates. Nevertheless there is abundant proof to show that something beside pure water is necessary in order to extinguish this disease absolutely.

GEORGE W. RAFTER, M. Am. Soc. C. E.—It is unfortunate that the author's determination of the organisms other than bacteria, present in the Ohio River, was not made quantitative as well as qualitative, especially since the Sedgwick-Rafter method of microscopical enumeration, as now used in the principal laboratories, renders it possible to make such determinations with very little labor. Moreover, the microscopical examination may assist in deciding how rapidly self-purification processes are operating. At the present time a mere list of the microscopical organisms is not considered of any special value, and it is to be hoped that if the author continues the interesting studies on which he is now engaged, he will remedy this defect in his future work. Mr. Rafter.

While the writer agrees with the final conclusion of the author, that only a water free from the influence of sewage contamination should be used for drinking, he is of the opinion that in cases where uncontaminated sources are out of reach, for financial and other reasons, filtration, if properly designed and efficiently operated, may be relied upon to remedy the evil. In towns where the water supply is wholly bad and the indifference or neglect of the municipal authorities leads to the ignoring of the whole question, individual citizens may still find relief by the use of properly designed, intermittently operated sand filters, which can be so arranged as to furnish an effluent free from the germs of infectious disease.

The author states that the normal habitat of the typhoid bacillus is in the intestine, liver, spleen and mesenteric gland of the human subject. This view at any rate is open to question, and a more probable one is that the typhoid bacillus is a saprophyte, capable of independent existence indefinitely outside the human body, with its normal habitat in the ground, the same as is the case with tetanus and anthrax.

Mr. Rafter. Final proof of the truth of this view is lacking, but so is proof of the correctness of the view taken by the author. All that can be done at present is to balance the probabilities as to which is the more rational. The author's view involves difficulty whenever it is necessary to explain the appearance of typhoid in localities previously free from it, and to which no typhoid patient has been imported. On the other hand, if the saprophytic character of typhoid is assumed, the difficulty vanishes and the explanation becomes easy. Travelers in regions remote from human habitations are sometimes attacked with typhoid, and while animals may have acted as the carriers of infection, this assumption also involves difficulties of no mean order.

Assuming, then, for the sake of the present argument, the correctness of the saprophytic view of the habit of the typhoid, it follows at once that the lack of relation between the results of filtration in London in the matter of the reduction of the number of bacteria and the reduction of the typhoid rate may not be due in any special degree to the imperfect action of the filters. In the vast city of London several hundred thousand people pass in and out every day, and when it is considered that under the saprophytic theory typhoid may grow at any place where there is organic filth to nourish it, and in view of the chances of infection which, therefore, arise from causes existing outside of the London water supply proper, but to which the users of that water supply are still more or less subject, the wonder really is, not that the reduction under the influence of efficient filtration is so little, but that it is so great.

The author is further disposed to assume that the typhoid bacillus passes through the filters in much larger number than the ordinary bacteria. On this point it appears that the experiments at Lawrence are decisive, especially those in which the typhoid bacilli to the number of several thousand per cubic centimeter were applied to filters with the result of either complete or nearly complete removal. As further showing the palpable incorrectness of the author's view that a smaller proportion of typhoid bacilli are removed than of the ordinary water bacteria, it is cited that, so far as known, the typhoid bacilli are very sparingly distributed in water, 25 per cu. cm. would be a very large proportion, much larger, it is believed, than has ever been found in any natural water. The author's view leads to the conclusion that the typhoid bacilli may pass through the best modern filters almost without any destructive action. But the contrary of this is shown by the experiments at Lawrence already referred to. It must be concluded, then, that the assumption of lack of efficiency of the London filters because of the smaller percentage of reduction in the typhoid death rate than of bacteria removal is possibly not founded on fact.

Mr. Hill. JOHN W. HILL, M. Am. Soc. C. E.—The most important question raised in discussion of the paper is upon the accuracy of the author's

statement, "if the typhoid germ is kept out of our dietetic water supplies, typhoid fever would cease to exist." In speaking of a dietetic water supply this is held by the author to include cooking water and water for washing uncooked articles of diet, as well as drinking water. In support of the view expressed in the paper, the author takes this opportunity to quote from three distinguished and reliable American authorities upon this subject: Mr. Hill.

"Out of every 100 cases of typhoid fever 99 come from infected drinking water."—(Dr. Cyrus Edson, Commissioner of Health, New York, in the New York *Tribune*, December 10th, 1894.)

"The diseases in which the death rate of Lawrence, Mass., especially exceeds that of other cities are typhoid fever and diarrhœal diseases, both of which are regarded as especially dependent upon the water used for drinking."—("Typhoid Fever in its Relation to Water Supply," by Mr. Hiram F. Mills, 1891.)

"In parts of Germany where the water supplies are controlled by Government, and are uniformly of excellent character, the death rate from typhoid fever has gradually declined to almost nothing."—(Mr. Allen Hazen, late chemist to the Massachusetts State Board of Health, in his discussion of this paper.)

Abundant testimony can be offered in support of the author's view, but it seems to be so generally accepted by "sound sanitarians" that it is not deemed advisable to consume space in further quotations from standard authority.

Common belief upon any abstruse subject is not always founded upon fact. But of those who have given the cause of typhoid fever most attention, substantially all are agreed upon an infected water as being the most probable cause of the continuous case and death rate from this disease. Mr. Hazen, in his discussion of the paper, has advanced a new cause or method of transmission of typhoid which, to the author, at least, is a revelation, viz., that the disease may be transmitted by personal contact, thus placing it among the contagious diseases. All medical and hygienic authorities which the author has had the opportunity of consulting upon the subject of typhoid fever universally negative the idea of personal transmission. The fact of several typhoid cases at about the same time in the same household can usually be accounted for without assuming personal transmission, and such experimental evidence as the author is familiar with upon the propagation of the disease is wholly at variance with Mr. Hazen's proposition.

In regard to the transmission of typhoid by milk, oysters, watercress and other vegetables, eaten uncooked, in nearly all such cases which have been fully investigated, the disease has been traced to an infected water with which such articles have come into contact. Absolute proof of this is not forthcoming in all cases, but the inference is fair from present knowledge that in probably no other manner can these articles of diet be infected. If the typhoid bacillus is in the air, even of hospital wards where the fever is prevailing, diligent search has

Mr. Hill. failed to reveal it. If the typhoid bacillus, or any other organism having the properties of the typhoid bacillus, is in the soil, the author is still to learn of it, excepting as conjectured by Mr. Rafter in his discussion of this paper.

If there be other causes than a typhoid infected water operating to produce the continuous case and death rate from typhoid fever, what are these causes? Has the Massachusetts State Board of Health, the foremost body of its kind in this country, demonstrated any other certain and continuous cause for typhoid fever?

These other causes, if there be any, should operate with the same force in London as in Lawrence, Mass.; yet it appears from the vital statistics of the two cities that this is not the case. London, with its large and heterogeneous population, should exhibit in greater degree than Lawrence the effects of typhoid infection from milk, personal uncleanliness and other causes mentioned, and yet it does not. Why should the death rate from typhoid fever at Lawrence, after the pure water was introduced, be from 15 to 24 times that of The Hague, or is it to be understood that the other causes of typhoid are more plentiful and active at Lawrence than at The Hague. Mr. Fuller offers no proof that personal cleanliness has any influence whatever on the transmission of typhoid fever; neither does Mr. Hazen submit any evidence in behalf of the personal contact theory, in the absence of which these new methods of transmission must be regarded as mere conjectures. A cause for the prevailing typhoid case and death rates must be explained from facts and not from the assumed facts which some one may think will be discovered a year or two hence, and by this standard the conclusion that an infected drinking water or water used in connection with some article of diet is the only probable cause cannot be avoided.

Mr. Hazen calls attention to some investigations of typhoid fever epidemics in Massachusetts during 1891 which were traced to infected milk, but he overlooks the conclusion arrived at by Professor Sedgwick in one or more of these, that the original source of infection was probably in a typhoid-tainted water used in the operations of the dairy. The same conclusion was reached in the investigation of the Montclair, N. J., typhoid epidemic, April, 1894.

In regard to the removal of the typhoid bacillus from water, the author has believed heretofore that this would be attended with the complete elimination of all typhoid fever so far as the local water supply is concerned, but the experience of Lawrence, Mass., since 1893 is calculated to shatter this belief. During this interval of time, the city has been supplied only with water from the new intermittent sand filter, based on the elaborate and exhaustive experiments on sand filtration at the Lawrence Experiment Station, and notwithstanding the fact that the water from this filter, according to report, is superior to

Mr. Hill.

that of many of the larger cities of the world, and goes forth to the people with the seal of approval of the State Board of Health, many people will not drink it, preferring the canal water of known sewage pollution, and of those who do drink it some die of typhoid fever. Or to be exact, after the Lawrence water has been put through this filter, and allowing for the deaths from typhoid of those known or supposed to have drunk the sewage-polluted canal water, the typhoid death rate of the city is still so large when compared with other cities of this country and Europe as to leave room for suspicion that, after all, it may be a mistake to render water so pure. Taking the Lawrence typhoid death rate for 1894 as 48 per 100 000 of population living, including deaths of those who drank the canal water; and 30 per 100 000 of population living for those victims who drank no canal water, it appears that even after allowing that nine of the 24 deaths for that year were properly chargeable to the canal water, the remainder produced a death rate twice that of Newark, N. J., and greater than that of many other cities not claiming extraordinary purity for their public water supplies.

This state of fact raises an inquiry whether the bacillus of Eberth is really the true germ of typhoid, or, admitting, as the Massachusetts State Board of Health insists, that it is, then it is necessary to look to some other cause or causes for the 34% of typhoid fever still prevailing in that city, for be it known that the bacillus itself (as claimed) is removed from the water by filtration.*

Possibly the following information furnished the author by a professional acquaintance in Boston, himself an expert chemist and water analyst, and very deeply interested in the problem of sand filtration, may throw some light on the continued comparatively high typhoid fever death rate of Lawrence, Mass. Writing under date of May 25th, he says:

"In regard to the Lawrence filter would say that while it was designed to act intermittently, I have had Prof. C—— make a number of visits to the plant and at each visit he has learned * * * that the (sand) bed had not been exposed to the air for a great many days, and * * * that there was just as much typhoid fever among the users of the filtered water as among the users of the canal water."

In regard to the claim for the Lawrence filter of the complete removal of the typhoid bacillus from water, it will be more correct to state that it was not found in the effluent. The difficulty of determining the presence of this bacillus in any water is well known to workers in this line, and it is not always safe to assume that the bacillus is not in a certain water because one does not happen to find it. The author has made many tests for the bacillus in the Ohio River water, using all the methods of which he is aware, in addition to a method of his own for the separation of the typhoid from other germs in water, but without success so far. And yet in the light of the high typhoid fever rate

* See the Report of Massachusetts State Board of Health, 1892, p. 531.

Mr. Hill. of Cincinnati, even the exponents of milk infection and personal contact and personal uncleanliness modes of transmission cannot doubt the presence of the bacillus probably at all seasons of the year in the Ohio River water. Because a thing cannot be found is not evidence of its non-existence, and in the light of the continued typhoid fever rate of Lawrence, the author feels that there is a mistake in assuming the complete removal of the typhoid bacillus from the Merrimack water by the Lawrence filter.

In regard to the statement by Mr. Rafter that the typhoid bacillus may find a habitat in the soil, this may be true (for a time) of a soil polluted with sewage carrying typhoid dejecta; and in such instances any bacteria in the sewage may be found in the soil. The Eberth bacillus can be found more readily and more certainly in the spleen of a victim dying early of the disease than in the ground, and the standard cultures of the germ which investigators use are always taken from this source.

In a soil where active nitrification is in progress the typhoid bacillus could not live for any length of time. Its action on inorganic matter is antagonistic to the nitrifying organisms, and as these are supposed to prevail in all soils supporting growing vegetation, it is difficult to see how the soil can be regarded as the source from which the bacillus is obtained, at least in cases of infection. Granting, however, that it may flourish in such a soil, the chance of taking it into the system from this source is very remote when compared with the possibility of infection from a sewage-polluted water. The normal habitat of the bacillus would naturally be that place where it is most frequently and surely found, and where it develops its highest properties. So far as is now known this is the human system, and the spleen is the organism from which it is obtained for culture purposes.

In speaking of the possibility of the typhoid bacillus passing through certain so-called "germ proof" and sand filters, the size of the germ was compared with such bacteria as the author has been able to find in the Ohio River and other local waters. Of over 20 species thus far differentiated only two are in any dimension smaller than *B. typhosus*, viz., *B. fluorescens liquefaciens*, and *B. violaceus*. Since the paper was written some experiments with the bacillus taken originally from a spleen and inoculated into sterilized Ohio River water indicate that it attains larger proportions and agrees more closely with the typical germ as described by the German investigators than when grown in the customary solutions. Never having found it in the raw water of the river it is not known whether it grows as large in unsterilized as in sterilized water where there are no other organisms to appropriate the food substance.

Under this head it may be of interest to note that the bacillus lives with full power to promptly reproduce its kind in the sterilized Ohio

Mr. Hill.

River water for more than 60 days, the exact time at which the water culture lost its power of reproduction not being noted, but further experiments will be made to determine this time. It may also be of interest to note that in carrying forward parallel cultures of *B. coli communis* (culture obtained from Berlin) and *B. typhosus* (two cultures from different spleens), the interesting fact was developed in transferring *B. coli communis* from an agar culture to potato, that the bacillus obtained a size as large as *B. subtilis*, and upon retransferring from potato to agar it regained its normal size. Several tests were made to confirm this, with the unfailing result that the bacillus obtained the large dimensions when inoculated from agar to potato.

In regard to the capacity of the Pasteur filter to restrain the passage of water bacteria, the author desires to supplement the data in the paper with the results from some recent tests.

Pasteur filter furnishing prescription water in drug store, Cincinnati, O.

	Plates inoculated.	Counted.	Bacteria per cubic centimeter.
No. 1.....	May 16th	May 23d	201
No. 2.....	May 16th	May 23d	287
No. 3.....	May 16th	May 23d	236

Pasteur filter in popular restaurant, Cincinnati, O.

	Plates inoculated.	Counted.	Bacteria per cubic centimeter.
No. 1..... ..	May 16th	May 23d	182
No. 2.....	May 16th	May 23d	167
No. 3.....	May 16th	May 23d	293

Bowden double-chamber filter in a popular restaurant, Cincinnati, O. This is a sand filter using alum as a coagulant.

	Plates inoculated.	Counted.	Bacteria per cubic centimeter.
No. 1.....	May 17th	May 21st	153
No. 2.....	May 17th	May 21st	180
No. 3.....	May 17th	May 21st	176

On these last plates many liquefying colonies appeared which compelled an early count to avoid a total loss of the test. Doubtless some slow-growing non-liquefying colonies had not grown in the four days of incubation at room temperature. It is proper to note that all these plates were made with slightly acid gelatine, which is known to be inimical to the growth of some species of water bacteria.

Referring to Mr. Riffle's statement of the number of cases of typhoid fever in this country, from such statistics as the author has been able to collect, the present annual death rate from typhoid and typho-malarial fevers, typhoid pneumonia, and complications involving typhoid symptoms, is upwards of 50 000; and the mortality seems

Mr. Hill. to average from 13 to 14% of the cases. On page 156, Vol. XXXII of the *Transactions* of the Society, the author shows the mortality from epidemics of typhoid fever in the cities of Lowell, Lawrence, and Springfield, Mass.; St. Louis, Mo., and Pittsburgh, Pa., to range from 4.2 to 52% of the cases reported. From the typhoid fever records of the Cincinnati Hospital for the past four years the mortality was 18.30, 12.00, 3.70, and 14.75% of the total cases admitted for the respective years (1891–94 inclusive).

In reply to Mr. Riffle's question the author has not noticed any reference to the use of a coagulent with the London filter-beds and understands that none is used.

It is held by many experienced investigators that the typhoid fever death rate of any city is the best test of the quality of the water supply of such city, and as interesting data in connection with this paper the following typhoid fever statistics are quoted from another article by the author. The statistics were collated for comparison with those of Lawrence, Mass., since the new filter was put in service:

DEATHS FROM TYPHOID FEVER PER 100 000 OF POPULATION LIVING.
CITIES SHOWING A LOWER DEATH RATE THAN LAWRENCE, MASS.

In America, 1894: New York, 17; Brooklyn, 15; Newark, N. J., 15; Detroit, 26; Cleveland, 27; Boston, 28; Dayton, O., 20; Milwaukee, 26; New Orleans, 28; Toronto, 17. In Europe, 1893: London, 16; Manchester, 25; Edinburgh, 14; Glasgow, 20; Paris, 25; Amsterdam, 16; Rotterdam, 5; The Hague, 2; Copenhagen, 9; Stockholm, 8; Christiania, 6; Berlin, 9; Hamburg, 18; Dresden, 4½; Breslau, 10; Munich, 15; Trieste, 17; Vienna, 7; Budapest, 15; Brussels, 27; Venice, 26.

CITIES SHOWING ABOUT THE SAME DEATH RATE AS LAWRENCE, MASS.

In America, 1894: Lawrence, 30; St. Louis, 31; Philadelphia, 32; Chicago, 31. In Europe, 1893: Rome, 34; Turin, 29.

CITIES SHOWING A HIGHER DEATH RATE THAN LAWRENCE, MASS.

In America, 1894: Baltimore, 48; Washington, D. C., 71; Pittsburg, 56; Buffalo, 36; San Francisco, 35; Cincinnati, 50; Louisville, 72; Providence, 47; Jersey City, 76; Lowell, 55. In Europe, 1893: Liverpool, 53; Dublin, 87; St. Petersburg, 51; Moscow, 40; Prague, 36; Milan, 62.

The author does not suppose that the proper purification of the water supply of any particular city will have an influence upon the typhoid rate at any great distance from the city, but it will eliminate typhoid so far as the water supply of that community is concerned, and without question, any measures looking to the extermination of typhoid fever must be applied to every community and be available in every household to be effective.